Stormwater Management Report

COAL MINE BROOK

616 Plantation Street
Worcester, Massachusetts

Prepared for:
City of Worcester
Mr. Robert Antonelli, Assistant Commissioner
c/o Cesar Valiente, Project Manager
Department of Public Works and Parks
50 Skyline Drive
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January 5, 2022

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COMMONWEALTH OF MASSACHUSETTS
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1/5/22

Daniel Gagne, PE

322801RP001A

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1.0 INTRODUCTION

The proposed project includes a stormwater management system designed to mitigate potential impacts the proposed project could have on the existing watershed. Stormwater controls have been proposed to control peak runoff rates, provide water quality, promote groundwater recharge and sediment removal. The proposed system has been designed to comply with:

- The 2008 Massachusetts Department of Environmental Protection (DEP) Stormwater Management Handbook,
- The Massachusetts Wetland Protection Act (310 CMR 10.00), and
- City of Worcester Wetland Protection Ordinance and Wetland Protection Regulations (Amended June 24, 2019)

The pre- and post-development hydrologic conditions were modeled using HydroCAD™ version 10.10 to demonstrate that post-development stormwater runoff rates will be less than or equal to the pre-development rates. Watershed maps with soil types as well as detailed analysis of the model results are also included. The following table summarizes the peak runoff rates for the pre- and post-development conditions.

Table 1: Pre- & Post-development Peak Runoff Rate Comparison, units are in cubic feet per second (cfs).

Storm Event	2 Year		10 Year		25 Year		100 Year	
	Pre	Post	*Pre*	Post	*Pre*	Post	*Pre*	Post
Design Point 1	*0.03*	0.03	*0.43*	0.34	*1.50*	1.13	*5.58*	4.73

2.0 PRE-DEVELOPMENT CONDITIONS

2.1 Site Conditions

The site is currently undeveloped with mostly wooded and overgrown areas containing remains of a bituminous concrete access drive areas, existing fencing, a trail path to the south of Coal Mine Brook, and gravel parking area to the east of the site. There are no existing stormwater controls located on the site. Runoff from the site currently drains to three primary locations: Plantation Street, Coal Mine Brook, and Lake Avenue North, all of which eventually outlet into Lake Quinisgamond to the east of the site. The final design point has been named correspondingly in the hydrologic analyses.

2.2 Soil Description

The Natural Resources Conservation Service (NRCS) lists the on-site soils as predominantly Hinckley loamy sand and Merrimac fine sandy loam.

The Hinckley loamy sand is an excessively drained soil consisting of 85% Hinckley and similar soils and 15% minor components. Generally, this soil is located in areas of summit, backslope, footslope, and shoulder and has a gravelly loamy sand layer that extends to about 19 inches below the surface followed by a very gravelly sand layer which extends to about 65 inches below the surface. NRCS classifies this type of soil as hydrologic class A soil.

The Merrimac fine sandy loam is a somewhat excessively drained soil consisting of 85% Merrimac and similar soils and 15% minor components. Generally, this soil is located in areas of summit, backslope, footslope, and shoulder and has a fine sandy loamy layer with gravel that extends to about 26 inches below the surface followed by a stratified gravel to very gravelly sand layer which extends to about 65 inches below the surface. NRCS classifies this type of soil as hydrologic class A soil.

On August 11, 2021, a Certified Soil Evaluator (Mark Mooney, EIT, SE #14347) conducted an on-site exploration of the soils within the vicinity of the proposed stormwater chambers and basin. The soils observed were consistent with the NRCS soil mapping. Soil textures consisted of sandy loam underlain by very gravelly sand. A summary of the test pits and soil logs are included in Attachment 1.

2.3 Hydrologic Analysis

Sub-catchment areas were delineated based on existing runoff patterns and topographic information. This information is shown on the *Pre-Development Conditions Hydrologic Areas Map* included in Attachment 2. Summaries of each area with respect to Curve Number and Time of Concentration calculations can be found in the model results also in Attachment 2.

3.0 POST-DEVELOPMENT CONDITIONS

3.1 Design Strategy

During the design phase of the site layout, consideration was given to conserving environmentally sensitive features and minimizing impact on the existing hydrology. To achieve this, extensive grading was avoided and the site was designed to match the existing terrain where feasible. Minimizing earthwork helps to maintain the existing drainage patterns to the maximum extent practicable under post-development conditions. On-site resource areas, such as the Bordering Vegetated Wetlands in the northern portion of the site, were excluded from the development envelope and will not be altered by the proposed project.

A stormwater management system has been designed to provide treatment for stormwater runoff associated with the proposed impervious surfaces on site. All stormwater BMPs were designed to treat a minimum of the first 1.0 inch of runoff generated by new parking areas. Proprietary stormwater treatment systems were designed to treat the runoff rate associated with the water quality volume in accordance with the requirements of the DEP Stormwater Handbook. Stormwater BMP sizing worksheets and water quality sizing calculations are included in Attachment 5 of this report.

To mitigate increased stormwater flow rates associated with the proposed impervious area, stormwater chambers and associated drainage structures have been proposed. Based on the data presented in the soil logs the stormwater chambers has been cited in the eastern and western portions of the site. The proposed stormwater systems will eventually discharge to Coal Mine Brook, consistent with the existing hydrology of the site.

3.2 Hydrologic Analysis

The established design points used in the pre-development conditions analysis were used in the post-development analysis for direct comparison. The tributary areas and flow paths were modified to reflect post-development conditions. See Attachment 3 for the *Post- Development Conditions Hydrologic Areas Map*. Summaries of each area with respect to Curve Number and Time of Concentration calculations can be found in the model results in Attachment 3.

3.3 Hydraulic Calculations

In compliance with City of Worcester requirements, the proposed storm drain system was analyzed based on the 25-year storm event using the Rational Formula. A watershed map and detailed hydraulic analysis are provided in Attachment 4.

3.4 Compliance with DEP Stormwater Management Standards

The proposed stormwater management system was designed in compliance with the ten (10) DEP Stormwater Management Standards. The following summary provides key information related to the proposed stormwater management system, its design elements, and mitigation measures for potential impacts.

STANDARD 1: **No new stormwater conveyance (e.g. outfalls) may discharge untreated stormwater directly to or cause erosion in wetlands or waters of the Commonwealth.**

There will be no direct discharge of untreated stormwater to nearby wetlands or waters of the Commonwealth. Runoff from all impervious areas of the site will be conveyed to stormwater management controls for infiltration, water quality treatment, and runoff rate attenuation prior to discharge to adjacent wetlands.

STANDARD 2: **Stormwater management systems shall be designed so that post-development peak discharge rates do not exceed pre-development peak discharge rates.**

The stormwater management design will control post-development peak discharge rates for the 2-, 10-, 25-, and 100-year, 24-hour storms so as to maintain pre-development peak discharge rates. Refer to Section 1.0 Introduction for a summary of the peak runoff rates.

STANDARD 3: **Loss of annual recharge to groundwater shall be eliminated or minimized through the use of environmentally sensitive site design, low impact development techniques, stormwater management practices and good operation and maintenance. At a minimum, the annual recharge from the post-development site shall approximate the annual recharge from pre-development conditions based on soil types. This Standard is met when the stormwater management system is designed to infiltrate the required recharge volume as determined in accordance with the Massachusetts Stormwater Handbook.**

The stormwater management system includes two subsurface infiltration areas that will effectively recharge groundwater on-site. Infiltration BMPs were sized using the static method based on the required recharge volume for the post-development site. As a result, annual recharge from the post-development site will approximate the annual recharge from the site under pre-development conditions. See Attachment 5 for stormwater BMP design worksheets and Groundwater Recharge Calculation.

STANDARD 4: **Stormwater management systems shall be designed to remove 80% of the average annual post-construction load of Total Suspended Solids (TSS).**

The proposed project will meet the water quality requirements of Standard 4 using on-site treatment trains that achieve 80% TSS removal. Refer to Attachment 5 for the TSS removal worksheets. Structural BMPs designed for water quality treatment, including the deep sump hooded catch basins, and Contech® water quality treatment systems, were sized to capture and treat the flow rate associated with the first 1.0-inch of runoff from proposed impervious surfaces. All proposed stormwater management BMPs will be operated and maintained to ensure continued water quality treatment of runoff. The Site Owner's Manual complies with the Long-Term Pollution Prevention Plan (Standard 4) and the Long-Term Operation and Maintenance Plan (Standard 9) requirements of the 2008 Massachusetts Department of Environmental Protection (MassDEP) Stormwater Management Standards. The Manual outlines source control and pollution prevention measures and maintenance requirements of stormwater best management practices (BMPs) associated with the proposed development.

STANDARD 5: **For land uses with higher potential pollutant loads (LUHPPLs), source control and pollution prevention shall be implemented in accordance with the Massachusetts Stormwater Handbook to eliminate or reduce the discharge of stormwater runoff from such land uses to the maximum extent practicable.**

The proposed project is not associated with stormwater discharges from land uses with higher potential pollutant loads.

STANDARD 6: **Stormwater discharges to critical areas must utilize certain stormwater management BMPs approved for critical areas. Critical areas are Outstanding Resource Waters, shellfish beds, swimming beaches, coldwater fisheries and recharge areas for public water supplies.**

The proposed BMPs are consistent with the Stormwater Management Handbook for use within Zone I, Zone II, and Cold Water Fishery critical area. The stormwater management system has been designed to capture and treat the first 1.0-inch of runoff as stipulated in the Stormwater Management Handbook. Deep sump hooded catch basins, and Contech® CDS1515 water quality treatment systems are proposed to remove pollutants from the first 1.0-inch of runoff from all new impervious areas. Adequate pretreatment will be provided before discharge.

STANDARD 7: **Redevelopment of previously developed sites must meet the Stormwater Management Standards to the maximum extent practicable. However, if it is not practicable to meet all the Standards, new (retrofitted or expanded) stormwater management systems must be designed to improve existing conditions.**

The proposed project is new development, and therefore this standard does not apply.

STANDARD 8: **A plan to control construction-related impacts during erosion, sedimentation and other pollutant sources during construction and land disturbance activities (construction period erosion, sedimentation, and pollution prevention plan) shall be developed and implemented.**

A Stormwater Pollution Prevention Plan (SWPPP) will be finalized and submitted prior to construction to comply with Section 3 of the NPDES Construction General Permit for Stormwater Discharges to address the requirements of Standard 8.

STANDARD 9: **A Long-Term Operation and Maintenance (O&M) Plan shall be developed and implemented to ensure that stormwater management systems function as designed.**

The Site Owner's Manual complies with the Long-Term Pollution Prevention Plan (Standard 4) and the Long-Term Operation and Maintenance Plan (Standard 9) requirements of the 2008 Massachusetts Department of Environmental Protection (MassDEP) Stormwater Management Standards. The Manual outlines source control and pollution prevention measures and maintenance requirements of the stormwater best management practices (BMPs) associated with the proposed development.

STANDARD 10: **All illicit discharges to the stormwater management system are prohibited.**

There will be no illicit discharges to the proposed stormwater management system associated with the proposed project. An Illicit Discharge Compliance Statement is provided on the following page.

3.5 Illicit Discharge Compliance Statement

An illicit discharge is any discharge to a stormwater management system that is not comprised entirely of stormwater, discharges from fire-fighting activities, and certain non-designated non-stormwater discharges.

To the best of my knowledge, no detectable illicit discharge exists on site. The site plans included with this report detail the storm sewers that convey stormwater on the site and demonstrate that these systems do not include the entry of an illicit discharge. A Site Owner's Manual is also included, which contains the Long Term Pollution Plan that outlines measures to prevent future illicit discharges. As the Site Owner, I will ultimately be responsible for implementing the Long Term Pollution Prevention Plan.

Signature: ______________________________
Owner's Name

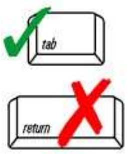
3.6 DEP's Checklist for a Stormwater Report

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

A. Introduction

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.



A Stormwater Report must be submitted with the Notice of Intent permit application to document compliance with the Stormwater Management Standards. The following checklist is NOT a substitute for the Stormwater Report (which should provide more substantive and detailed information) but is offered here as a tool to help the applicant organize their Stormwater Management documentation for their Report and for the reviewer to assess this information in a consistent format. As noted in the Checklist, the Stormwater Report must contain the engineering computations and supporting information set forth in Volume 3 of the Massachusetts Stormwater Handbook. The Stormwater Report must be prepared and certified by a Registered Professional Engineer (RPE) licensed in the Commonwealth.

The Stormwater Report must include:

- The Stormwater Checklist completed and stamped by a Registered Professional Engineer (see page 2) that certifies that the Stormwater Report contains all required submittals.[1] This Checklist is to be used as the cover for the completed Stormwater Report.
- Applicant/Project Name
- Project Address
- Name of Firm and Registered Professional Engineer that prepared the Report
- Long-Term Pollution Prevention Plan required by Standards 4-6
- Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan required by Standard 8[2]
- Operation and Maintenance Plan required by Standard 9

In addition to all plans and supporting information, the Stormwater Report must include a brief narrative describing stormwater management practices, including environmentally sensitive site design and LID techniques, along with a diagram depicting runoff through the proposed BMP treatment train. Plans are required to show existing and proposed conditions, identify all wetland resource areas, NRCS soil types, critical areas, Land Uses with Higher Potential Pollutant Loads (LUHPPL), and any areas on the site where infiltration rate is greater than 2.4 inches per hour. The Plans shall identify the drainage areas for both existing and proposed conditions at a scale that enables verification of supporting calculations.

As noted in the Checklist, the Stormwater Management Report shall document compliance with each of the Stormwater Management Standards as provided in the Massachusetts Stormwater Handbook. The soils evaluation and calculations shall be done using the methodologies set forth in Volume 3 of the Massachusetts Stormwater Handbook.

To ensure that the Stormwater Report is complete, applicants are required to fill in the Stormwater Report Checklist by checking the box to indicate that the specified information has been included in the Stormwater Report. If any of the information specified in the checklist has not been submitted, the applicant must provide an explanation. The completed Stormwater Report Checklist and Certification must be submitted with the Stormwater Report.

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[1] The Stormwater Report may also include the Illicit Discharge Compliance Statement required by Standard 10. If not included in the Stormwater Report, the Illicit Discharge Compliance Statement must be submitted prior to the discharge of stormwater runoff to the post-construction best management practices.

[2] For some complex projects, it may not be possible to include the Construction Period Erosion and Sedimentation Control Plan in the Stormwater Report. In that event, the issuing authority has the discretion to issue an Order of Conditions that approves the project and includes a condition requiring the proponent to submit the Construction Period Erosion and Sedimentation Control Plan before commencing any land disturbance activity on the site.

Checklist for Stormwater Report

B. Stormwater Checklist and Certification

The following checklist is intended to serve as a guide for applicants as to the elements that ordinarily need to be addressed in a complete Stormwater Report. The checklist is also intended to provide conservation commissions and other reviewing authorities with a summary of the components necessary for a comprehensive Stormwater Report that addresses the ten Stormwater Standards.

Note: Because stormwater requirements vary from project to project, it is possible that a complete Stormwater Report may not include information on some of the subjects specified in the Checklist. If it is determined that a specific item does not apply to the project under review, please note that the item is not applicable (N.A.) and provide the reasons for that determination.

A complete checklist must include the Certification set forth below signed by the Registered Professional Engineer who prepared the Stormwater Report.

Registered Professional Engineer's Certification

I have reviewed the Stormwater Report, including the soil evaluation, computations, Long-term Pollution Prevention Plan, the Construction Period Erosion and Sedimentation Control Plan (if included), the Long-term Post-Construction Operation and Maintenance Plan, the Illicit Discharge Compliance Statement (if included) and the plans showing the stormwater management system, and have determined that they have been prepared in accordance with the requirements of the Stormwater Management Standards as further elaborated by the Massachusetts Stormwater Handbook. I have also determined that the information presented in the Stormwater Checklist is accurate and that the information presented in the Stormwater Report accurately reflects conditions at the site as of the date of this permit application.

Registered Professional Engineer Block and Signature

COMMONWEALTH OF MASSACHUSETTS
DANIEL M. GAGNE
CIVIL
No. 48665
REGISTERED
PROFESSIONAL ENGINEER
1/5/22

01/05/2022

Signature and Date

Checklist

Project Type: Is the application for new development, redevelopment, or a mix of new and redevelopment?

☒ New development

☐ Redevelopment

☐ Mix of New Development and Redevelopment

Checklist for Stormwater Report

Checklist (continued)

LID Measures: Stormwater Standards require LID measures to be considered. Document what environmentally sensitive design and LID Techniques were considered during the planning and design of the project:

- ☐ No disturbance to any Wetland Resource Areas
- ☐ Site Design Practices (e.g. clustered development, reduced frontage setbacks)
- ☐ Reduced Impervious Area (Redevelopment Only)
- ☐ Minimizing disturbance to existing trees and shrubs
- ☐ LID Site Design Credit Requested:
  - ☐ Credit 1
  - ☐ Credit 2
  - ☐ Credit 3
- ☐ Use of “country drainage” versus curb and gutter conveyance and pipe
- ☐ Bioretention Cells (includes Rain Gardens)
- ☐ Constructed Stormwater Wetlands (includes Gravel Wetlands designs)
- ☐ Treebox Filter
- ☐ Water Quality Swale
- ☐ Grass Channel
- ☐ Green Roof
- ☐ Other (describe): ____________________

Standard 1: No New Untreated Discharges

- ☒ No new untreated discharges
- ☒ Outlets have been designed so there is no erosion or scour to wetlands and waters of the Commonwealth
- ☒ Supporting calculations specified in Volume 3 of the Massachusetts Stormwater Handbook included.

Checklist (continued)

Standard 2: Peak Rate Attenuation

☐ Standard 2 waiver requested because the project is located in land subject to coastal storm flowage and stormwater discharge is to a wetland subject to coastal flooding.

☐ Evaluation provided to determine whether off-site flooding increases during the 100-year 24-hour storm.

☒ Calculations provided to show that post-development peak discharge rates do not exceed pre-development rates for the 2-year and 10-year 24-hour storms. If evaluation shows that off-site flooding increases during the 100-year 24-hour storm, calculations are also provided to show that post-development peak discharge rates do not exceed pre-development rates for the 100-year 24-hour storm.

Standard 3: Recharge

☒ Soil Analysis provided.

☒ Required Recharge Volume calculation provided.

☐ Required Recharge volume reduced through use of the LID site Design Credits.

☒ Sizing the infiltration, BMPs is based on the following method: Check the method used.

☒ Static ☐ Simple Dynamic ☐ Dynamic Field[1]

☐ Runoff from all impervious areas at the site discharging to the infiltration BMP.

☒ Runoff from all impervious areas at the site is *not* discharging to the infiltration BMP and calculations are provided showing that the drainage area contributing runoff to the infiltration BMPs is sufficient to generate the required recharge volume.

☐ Recharge BMPs have been sized to infiltrate the Required Recharge Volume.

☐ Recharge BMPs have been sized to infiltrate the Required Recharge Volume *only* to the maximum extent practicable for the following reason:

- ☐ Site is comprised solely of C and D soils and/or bedrock at the land surface
- ☐ M.G.L. c. 21E sites pursuant to 310 CMR 40.0000
- ☐ Solid Waste Landfill pursuant to 310 CMR 19.000
- ☐ Project is otherwise subject to Stormwater Management Standards only to the maximum extent practicable.

☒ Calculations showing that the infiltration BMPs will drain in 72 hours are provided.

☐ Property includes a M.G.L. c. 21E site or a solid waste landfill and a mounding analysis is included.

[1] 80% TSS removal is required prior to discharge to infiltration BMP if Dynamic Field method is used.

Checklist (continued)

Standard 3: Recharge (continued)

☒ The infiltration BMP is used to attenuate peak flows during storms greater than or equal to the 10-year 24-hour storm and separation to seasonal high groundwater is less than 4 feet and a mounding analysis is provided.

☐ Documentation is provided showing that infiltration BMPs do not adversely impact nearby wetland resource areas.

Standard 4: Water Quality

The Long-Term Pollution Prevention Plan typically includes the following:

- Good housekeeping practices;
- Provisions for storing materials and waste products inside or under cover;
- Vehicle washing controls;
- Requirements for routine inspections and maintenance of stormwater BMPs;
- Spill prevention and response plans;
- Provisions for maintenance of lawns, gardens, and other landscaped areas;
- Requirements for storage and use of fertilizers, herbicides, and pesticides;
- Pet waste management provisions;
- Provisions for operation and management of septic systems;
- Provisions for solid waste management;
- Snow disposal and plowing plans relative to Wetland Resource Areas;
- Winter Road Salt and/or Sand Use and Storage restrictions;
- Street sweeping schedules;
- Provisions for prevention of illicit discharges to the stormwater management system;
- Documentation that Stormwater BMPs are designed to provide for shutdown and containment in the event of a spill or discharges to or near critical areas or from LUHPPL;
- Training for staff or personnel involved with implementing Long-Term Pollution Prevention Plan;
- List of Emergency contacts for implementing Long-Term Pollution Prevention Plan.

☒ A Long-Term Pollution Prevention Plan is attached to Stormwater Report and is included as an attachment to the Wetlands Notice of Intent.

☒ Treatment BMPs subject to the 44% TSS removal pretreatment requirement and the one inch rule for calculating the water quality volume are included, and discharge:

  ☒ is within the Zone II or Interim Wellhead Protection Area

  ☐ is near or to other critical areas

  ☐ is within soils with a rapid infiltration rate (greater than 2.4 inches per hour)

  ☐ involves runoff from land uses with higher potential pollutant loads.

☐ The Required Water Quality Volume is reduced through use of the LID site Design Credits.

☒ Calculations documenting that the treatment train meets the 80% TSS removal requirement and, if applicable, the 44% TSS removal pretreatment requirement, are provided.

Checklist (continued)

Standard 4: Water Quality (continued)

☒ The BMP is sized (and calculations provided) based on:

- ☐ The ½" or 1" Water Quality Volume or
- ☒ The equivalent flow rate associated with the Water Quality Volume and documentation is provided showing that the BMP treats the required water quality volume.

☒ The applicant proposes to use proprietary BMPs, and documentation supporting use of proprietary BMP and proposed TSS removal rate is provided. This documentation may be in the form of the propriety BMP checklist found in Volume 2, Chapter 4 of the Massachusetts Stormwater Handbook and submitting copies of the TARP Report, STEP Report, and/or other third party studies verifying performance of the proprietary BMPs.

☐ A TMDL exists that indicates a need to reduce pollutants other than TSS and documentation showing that the BMPs selected are consistent with the TMDL is provided.

Standard 5: Land Uses With Higher Potential Pollutant Loads (LUHPPLs)

☐ The NPDES Multi-Sector General Permit covers the land use and the Stormwater Pollution Prevention Plan (SWPPP) has been included with the Stormwater Report.

☐ The NPDES Multi-Sector General Permit covers the land use and the SWPPP will be submitted ***prior to*** the discharge of stormwater to the post-construction stormwater BMPs.

☐ The NPDES Multi-Sector General Permit does ***not*** cover the land use.

☐ LUHPPLs are located at the site and industry specific source control and pollution prevention measures have been proposed to reduce or eliminate the exposure of LUHPPLs to rain, snow, snow melt and runoff, and been included in the long term Pollution Prevention Plan.

☐ All exposure has been eliminated.

☐ All exposure has ***not*** been eliminated and all BMPs selected are on MassDEP LUHPPL list.

☐ The LUHPPL has the potential to generate runoff with moderate to higher concentrations of oil and grease (e.g. all parking lots with >1000 vehicle trips per day) and the treatment train includes an oil grit separator, a filtering bioretention area, a sand filter or equivalent.

Standard 6: Critical Areas

☒ The discharge is near or to a critical area and the treatment train includes only BMPs that MassDEP has approved for stormwater discharges to or near that particular class of critical area.

☒ Critical areas and BMPs are identified in the Stormwater Report.

Checklist (continued)

Standard 7: Redevelopments and Other Projects Subject to the Standards only to the maximum extent practicable

☐ The project is subject to the Stormwater Management Standards only to the maximum Extent Practicable as a:

- ☐ Limited Project
- ☐ Small Residential Projects: 5-9 single family houses or 5-9 units in a multi-family development provided there is no discharge that may potentially affect a critical area.
- ☐ Small Residential Projects: 2-4 single family houses or 2-4 units in a multi-family development with a discharge to a critical area
- ☐ Marina and/or boatyard provided the hull painting, service and maintenance areas are protected from exposure to rain, snow, snow melt and runoff
- ☐ Bike Path and/or Foot Path
- ☐ Redevelopment Project
- ☐ Redevelopment portion of mix of new and redevelopment.

☐ Certain standards are not fully met (Standard No. 1, 8, 9, and 10 must always be fully met) and an explanation of why these standards are not met is contained in the Stormwater Report.

☐ The project involves redevelopment and a description of all measures that have been taken to improve existing conditions is provided in the Stormwater Report. The redevelopment checklist found in Volume 2 Chapter 3 of the Massachusetts Stormwater Handbook may be used to document that the proposed stormwater management system (a) complies with Standards 2, 3 and the pretreatment and structural BMP requirements of Standards 4-6 to the maximum extent practicable and (b) improves existing conditions.

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control

A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan must include the following information:

- Narrative;
- Construction Period Operation and Maintenance Plan;
- Names of Persons or Entity Responsible for Plan Compliance;
- Construction Period Pollution Prevention Measures;
- Erosion and Sedimentation Control Plan Drawings;
- Detail drawings and specifications for erosion control BMPs, including sizing calculations;
- Vegetation Planning;
- Site Development Plan;
- Construction Sequencing Plan;
- Sequencing of Erosion and Sedimentation Controls;
- Operation and Maintenance of Erosion and Sedimentation Controls;
- Inspection Schedule;
- Maintenance Schedule;
- Inspection and Maintenance Log Form.

☐ A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan containing the information set forth above has been included in the Stormwater Report.

Checklist (continued)

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control (continued)

☐ The project is highly complex and information is included in the Stormwater Report that explains why it is not possible to submit the Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan with the application. A Construction Period Pollution Prevention and Erosion and Sedimentation Control has ***not*** been included in the Stormwater Report but will be submitted ***before*** land disturbance begins.

☐ The project is ***not*** covered by a NPDES Construction General Permit.

☐ The project is covered by a NPDES Construction General Permit and a copy of the SWPPP is in the Stormwater Report.

☒ The project is covered by a NPDES Construction General Permit but no SWPPP been submitted. The SWPPP will be submitted BEFORE land disturbance begins.

Standard 9: Operation and Maintenance Plan

☒ The Post Construction Operation and Maintenance Plan is included in the Stormwater Report and includes the following information:

- ☒ Name of the stormwater management system owners;
- ☒ Party responsible for operation and maintenance;
- ☒ Schedule for implementation of routine and non-routine maintenance tasks;
- ☒ Plan showing the location of all stormwater BMPs maintenance access areas;
- ☒ Description and delineation of public safety features;
- ☒ Estimated operation and maintenance budget; and
- ☒ Operation and Maintenance Log Form.

☐ The responsible party is ***not*** the owner of the parcel where the BMP is located and the Stormwater Report includes the following submissions:

- ☐ A copy of the legal instrument (deed, homeowner's association, utility trust or other legal entity) that establishes the terms of and legal responsibility for the operation and maintenance of the project site stormwater BMPs;
- ☐ A plan and easement deed that allows site access for the legal entity to operate and maintain BMP functions.

Standard 10: Prohibition of Illicit Discharges

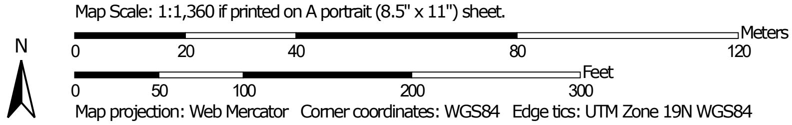
☒ The Long-Term Pollution Prevention Plan includes measures to prevent illicit discharges;

☒ An Illicit Discharge Compliance Statement is attached;

☐ NO Illicit Discharge Compliance Statement is attached but will be submitted ***prior to*** the discharge of any stormwater to post-construction BMPs.

Attachment 1
Soil Data

Map Scale: 1:1,360 if printed on A portrait (8.5" x 11") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 19N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Worcester County, Massachusetts, Northeastern Part
Survey Area Data: Version 15, Jun 10, 2020

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jul 26, 2019—Oct 5, 2019

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
245B	Hinckley loamy sand, 3 to 8 percent slopes	A	2.4	41.9%
254B	Merrimac fine sandy loam, 3 to 8 percent slopes	A	2.3	41.2%
254C	Merrimac fine sandy loam, 8 to 15 percent slopes	A	0.2	3.7%
651	Udorthents, smoothed		0.8	13.3%
Totals for Area of Interest			**5.7**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

B E A L S + T H O M A S
Soil Test Pit Log

3228.01- Worcester, MA
8/11/2021

Deep Observation Hole Number: TP - 1

Depth (in.)	Soil Horizon/ Layer	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features			Soil Texture (USDA)	Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
			Depth	Color	Percent		Gravel	Cobbles & Stones			
0-6	A	10YR 5/1				Sandy Loam	0 - 5	0 - 5	Granular	Friable	
6-12	Bw	10YR 5/3				Sandy Loam	0-5	0-5	Massive	Friable	
12-72	C1	5YR 4/3				Sandy Loam	5-10	10-15	Massive	Friable	
72-128	C2	7.5YR 4/1				V.Grav. Sand	40-50	5-10	Single Grain	Loose	

Additional Notes:
No water or redox observed

BEALS + THOMAS
Soil Test Pit Log

3228.01- Worcester, MA
8/11/2021

Deep Observation Hole Number: TP - 2

Depth (in.)	Soil Horizon/ Layer	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features			Soil Texture (USDA)	Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
			Depth	Color	Percent		Gravel	Cobbles & Stones			
0-4	A	10YR 5/1				Sandy Loam	0 - 5	0 - 5	Granular	Friable	
4-12	Bw	10YR 5/3				Sandy Loam	0-5	0-5	Massive	Friable	
12-36	C1	5YR 4/3				Sandy Loam	5-10	10-15	Massive	Friable	
36-110	C2	7.5YR 4/1				V.Grav. Sand	40-50	5-10	Single Grain	Loose	

Additional Notes:
No water or redox observed

B E A L S + T H O M A S
Soil Test Pit Log

3228.01- Worcester, MA
8/11/2021

Deep Observation Hole Number: TP - 3

Depth (in.)	Soil Horizon/ Layer	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features			Soil Texture (USDA)	Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
			Depth	Color	Percent		Gravel	Cobbles & Stones			
0-4	A	10YR 5/1				Sandy Loam	0 - 5	0 - 5	Granular	Friable	
4-20	Bw	10YR 5/3				Sandy Loam	0-5	0-5	Massive	Friable	
20-124	C	5YR 3/4				V.Grav. Sand	40-50	5-10	Single Grain	Loose	

Additional Notes:
No water or redox observed

BEALS + THOMAS
Soil Test Pit Log

3228.01- Worcester, MA
8/11/2021

Deep Observation Hole Number: TP - 4

Depth (in.)	Soil Horizon/ Layer	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features			Soil Texture (USDA)	Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
			Depth	Color	Percent		Gravel	Cobbles & Stones			
0-6	A					Sandy Loam	0 - 5	0 - 5	Granular	Friable	
6-12	Bw					Sandy Loam			Massive	Friable	
12-72	C1	5YR 4/3				Sandy Loam	0-5	10-15	Massive	Friable	
72-128	C2	7.5YR 4/1				V. Grav. Sand	40-50	5-10	Single Grain	Loose	

Additional Notes:
No water or redox observed

BEALS + THOMAS
Soil Test Pit Log

3228.01- Worcester, MA
8/11/2021

Deep Observation Hole Number: TP - 5

Depth (in.)	Soil Horizon/ Layer	Soil Matrix: Color- Moist (Munsell)	Redoximorphic Features			Soil Texture (USDA)	Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
			Depth	Color	Percent		Gravel	Cobbles & Stones			
0-4	A	10YR 4/3				Sandy Loam	0 - 5	0 - 5	Granular	Friable	
4-14	Bw	10YR 5/4				Sandy Loam			Massive	Friable	
14-24	C1	10YR 6/3				Sand	0-5	0-5	Single Grain	Loose	
24-130	C2	7.5YR 4/1				V. Grav. Sand	40-50	5-10	Single Grain	Loose	

Additional Notes:
No water or redox observed

BEALS + THOMAS
Soil Test Pit Log

3228.01- Worcester, MA
8/11/2021

Deep Observation Hole Number: TP - 6

Depth (in.)	Soil Horizon/ Layer	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features			Soil Texture (USDA)	Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
			Depth	Color	Percent		Gravel	Cobbles & Stones			
0-4	A	10YR 4/3				Sandy Loam	0 - 5	0 - 5	Granular	Friable	
4-12	Bw	10YR 5/4				Sandy Loam			Massive	Friable	
12-20	C1	10YR 5/1				Sandy Loam	5-10	5-10	Massive	Friable	
20-46	C2	10YR 5/4				V. Grav. Sand	40-50	20-25	Single Grain	Loose	
46-128	C3	10YR 3/1				V. Grav. Sand	40-50	20-25	Single Grain	Loose	

Additional Notes:
No water or redox observed

BEALS + THOMAS
Soil Test Pit Log

3228.01- Worcester, MA
8/11/2021

Deep Observation Hole Number: TP - 7

Depth (in.)	Soil Horizon/ Layer	Soil Matrix: Color-Moist (Munsell)	Redoximorphic Features			Soil Texture (USDA)	Coarse Fragments % by Volume		Soil Structure	Soil Consistence (Moist)	Other
			Depth	Color	Percent		Gravel	Cobbles & Stones			
0-4	A	10YR 4/3				Sandy Loam	0 - 5	0 - 5	Granular	Friable	
4-24	Bw	10YR 5/4				Sandy Loam			Massive	Friable	
24-40	C1	10YR 5/4				Sandy Loam			Massive	Friable	
40-130	C2	10YR 3/1				V. Grav. Sand	40-50	20-25	Single Grain	Loose	

Additional Notes:
No water or redox observed

Attachment 2
Pre-Development Hydrologic Analysis

PRE-DEVELOPMENT CONDITIONS HYDROLOGY CALCULATION SUMMARY

OBJECTIVE

To determine the pre-development peak rates of runoff from the site for the 2, 10, 25, & 100-year storm events at the design points.

CONCLUSION(S)

Peak Runoff Rates (CFS):

Storm Event	DP-1
2-Year	0.03
10-Year	0.43
25-Year	1.50
100-Year	5.58

CALCULATION METHODS

1. Runoff curve numbers (CN), time-of-concentration (Tc), and runoff rates were calculated based on TR-55 methodology.
2. AutoCAD 2019 computer program was utilized for digitizing ground cover areas.
3. Peak runoff runoff rates were computed using HydroCAD version 10.10.
4. Design storms calculated using NOAA Atlas 14 point precipitation frequency estimates.

ASSUMPTIONS

1. The ground cover types were determined using aerial imagery. Hydrologic soil groups based on United States Department of Agriculture, NRCS Soil Survey map information.
2. Stormwater runoff from offsite tributary areas was included in the calculations.

SOURCES OF DATA/ EQUATIONS

1. Pre-Development Conditions Hydrologic Areas Map prepared by Beals and Thomas, Inc. File No. 322801P004A-001.
2. NRCS Soil Survey for Worcester County, downloaded from Web Soil Survey on 05/18/2021.
3. TR-55 urban Hydrology for Small Watersheds, SCS, 1986.
4. Massachusetts DEP Stormwater Management Handbook, February 2008.

REV	CALC. BY	DATE	CHECKED BY	DATE	APPROVED BY	DATE
0	NBB	01/03/2022	DMG	01/03/2022	DMG	01/04/2022

NBB/322801CS001

NOAA Atlas 14, Volume 10, Version 3
Location name: Worcester, Massachusetts, USA*
Latitude: 42.2908°, Longitude: -71.7595°
Elevation: 363.65 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**	**1000**
5-min	**0.345** (0.272-0.432)	**0.405** (0.319-0.508)	**0.504** (0.396-0.635)	**0.586** (0.457-0.742)	**0.699** (0.526-0.925)	**0.785** (0.577-1.06)	**0.873** (0.621-1.23)	**0.968** (0.655-1.40)	**1.10** (0.715-1.66)	**1.21** (0.763-1.86)
10-min	**0.489** (0.385-0.612)	**0.574** (0.452-0.720)	**0.714** (0.560-0.899)	**0.830** (0.648-1.05)	**0.990** (0.745-1.31)	**1.11** (0.818-1.51)	**1.24** (0.880-1.74)	**1.37** (0.928-1.99)	**1.56** (1.01-2.35)	**1.71** (1.08-2.63)
15-min	**0.575** (0.453-0.720)	**0.675** (0.532-0.847)	**0.840** (0.659-1.06)	**0.977** (0.762-1.24)	**1.17** (0.877-1.54)	**1.31** (0.962-1.77)	**1.46** (1.03-2.04)	**1.61** (1.09-2.34)	**1.83** (1.19-2.76)	**2.01** (1.27-3.09)
30-min	**0.776** (0.612-0.972)	**0.913** (0.719-1.15)	**1.14** (0.892-1.43)	**1.32** (1.03-1.68)	**1.58** (1.19-2.09)	**1.77** (1.31-2.40)	**1.97** (1.40-2.77)	**2.19** (1.48-3.17)	**2.49** (1.62-3.75)	**2.73** (1.73-4.20)
60-min	**0.977** (0.770-1.22)	**1.15** (0.906-1.44)	**1.43** (1.13-1.80)	**1.67** (1.30-2.11)	**1.99** (1.50-2.64)	**2.24** (1.65-3.03)	**2.49** (1.77-3.50)	**2.77** (1.87-4.01)	**3.14** (2.04-4.73)	**3.45** (2.18-5.30)
2-hr	**1.23** (0.973-1.53)	**1.46** (1.16-1.82)	**1.84** (1.45-2.30)	**2.16** (1.69-2.72)	**2.59** (1.97-3.42)	**2.92** (2.17-3.95)	**3.26** (2.35-4.60)	**3.66** (2.48-5.27)	**4.24** (2.76-6.35)	**4.73** (3.00-7.23)
3-hr	**1.40** (1.12-1.74)	**1.68** (1.34-2.08)	**2.13** (1.69-2.65)	**2.50** (1.97-3.14)	**3.02** (2.30-3.98)	**3.40** (2.54-4.60)	**3.81** (2.76-5.38)	**4.30** (2.92-6.17)	**5.02** (3.28-7.49)	**5.63** (3.58-8.58)
6-hr	**1.77** (1.42-2.18)	**2.13** (1.71-2.63)	**2.73** (2.18-3.38)	**3.22** (2.55-4.01)	**3.90** (2.99-5.12)	**4.41** (3.31-5.93)	**4.95** (3.61-6.96)	**5.60** (3.82-8.00)	**6.59** (4.31-9.76)	**7.43** (4.74-11.2)
12-hr	**2.21** (1.78-2.71)	**2.68** (2.16-3.29)	**3.45** (2.77-4.25)	**4.09** (3.26-5.06)	**4.96** (3.83-6.47)	**5.61** (4.24-7.50)	**6.31** (4.63-8.81)	**7.15** (4.90-10.1)	**8.42** (5.52-12.4)	**9.49** (6.07-14.3)
24-hr	**2.63** (2.13-3.20)	**3.20** (2.60-3.91)	**4.15** (3.36-5.08)	**4.93** (3.96-6.07)	**6.01** (4.67-7.80)	**6.81** (5.18-9.06)	**7.68** (5.66-10.7)	**8.72** (5.99-12.3)	**10.3** (6.78-15.1)	**11.6** (7.47-17.4)
2-day	**2.96** (2.42-3.58)	**3.63** (2.97-4.40)	**4.74** (3.86-5.76)	**5.65** (4.57-6.92)	**6.92** (5.40-8.92)	**7.85** (6.00-10.4)	**8.86** (6.58-12.3)	**10.1** (6.97-14.2)	**12.0** (7.94-17.5)	**13.7** (8.81-20.3)
3-day	**3.21** (2.63-3.87)	**3.93** (3.23-4.75)	**5.12** (4.18-6.20)	**6.11** (4.96-7.44)	**7.46** (5.85-9.59)	**8.46** (6.50-11.2)	**9.55** (7.12-13.2)	**10.9** (7.54-15.2)	**13.0** (8.59-18.8)	**14.8** (9.53-21.8)
4-day	**3.44** (2.83-4.14)	**4.20** (3.46-5.06)	**5.44** (4.46-6.58)	**6.48** (5.27-7.87)	**7.90** (6.21-10.1)	**8.94** (6.88-11.8)	**10.1** (7.53-13.9)	**11.5** (7.96-16.0)	**13.7** (9.05-19.7)	**15.5** (10.0-22.9)
7-day	**4.11** (3.40-4.91)	**4.93** (4.08-5.90)	**6.28** (5.17-7.55)	**7.40** (6.05-8.95)	**8.94** (7.05-11.4)	**10.1** (7.77-13.1)	**11.3** (8.45-15.4)	**12.8** (8.90-17.7)	**15.0** (10.0-21.6)	**17.0** (11.0-24.8)
10-day	**4.77** (3.96-5.68)	**5.63** (4.67-6.72)	**7.03** (5.82-8.43)	**8.20** (6.74-9.89)	**9.81** (7.76-12.4)	**11.0** (8.50-14.3)	**12.3** (9.17-16.6)	**13.8** (9.62-19.0)	**16.0** (10.7-22.9)	**17.9** (11.6-26.1)
20-day	**6.81** (5.70-8.06)	**7.72** (6.46-9.16)	**9.22** (7.67-11.0)	**10.5** (8.65-12.5)	**12.2** (9.66-15.2)	**13.5** (10.4-17.2)	**14.8** (11.0-19.6)	**16.2** (11.4-22.1)	**18.2** (12.2-25.8)	**19.7** (12.8-28.6)
30-day	**8.51** (7.16-10.0)	**9.46** (7.94-11.2)	**11.0** (9.20-13.1)	**12.3** (10.2-14.7)	**14.1** (11.2-17.4)	**15.4** (11.9-19.5)	**16.8** (12.4-21.9)	**18.1** (12.8-24.6)	**19.9** (13.4-28.0)	**21.2** (13.8-30.6)
45-day	**10.6** (8.98-12.5)	**11.6** (9.79-13.7)	**13.2** (11.1-15.6)	**14.6** (12.1-17.3)	**16.4** (13.1-20.2)	**17.8** (13.8-22.4)	**19.2** (14.2-24.9)	**20.5** (14.5-27.7)	**22.0** (14.9-30.9)	**23.1** (15.1-33.2)
60-day	**12.4** (10.5-14.5)	**13.4** (11.3-15.8)	**15.1** (12.7-17.8)	**16.5** (13.8-19.5)	**18.4** (14.7-22.5)	**19.9** (15.4-24.8)	**21.3** (15.8-27.4)	**22.5** (16.0-30.3)	**23.9** (16.2-33.5)	**24.8** (16.3-35.6)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.
Please refer to NOAA Atlas 14 document for more information.

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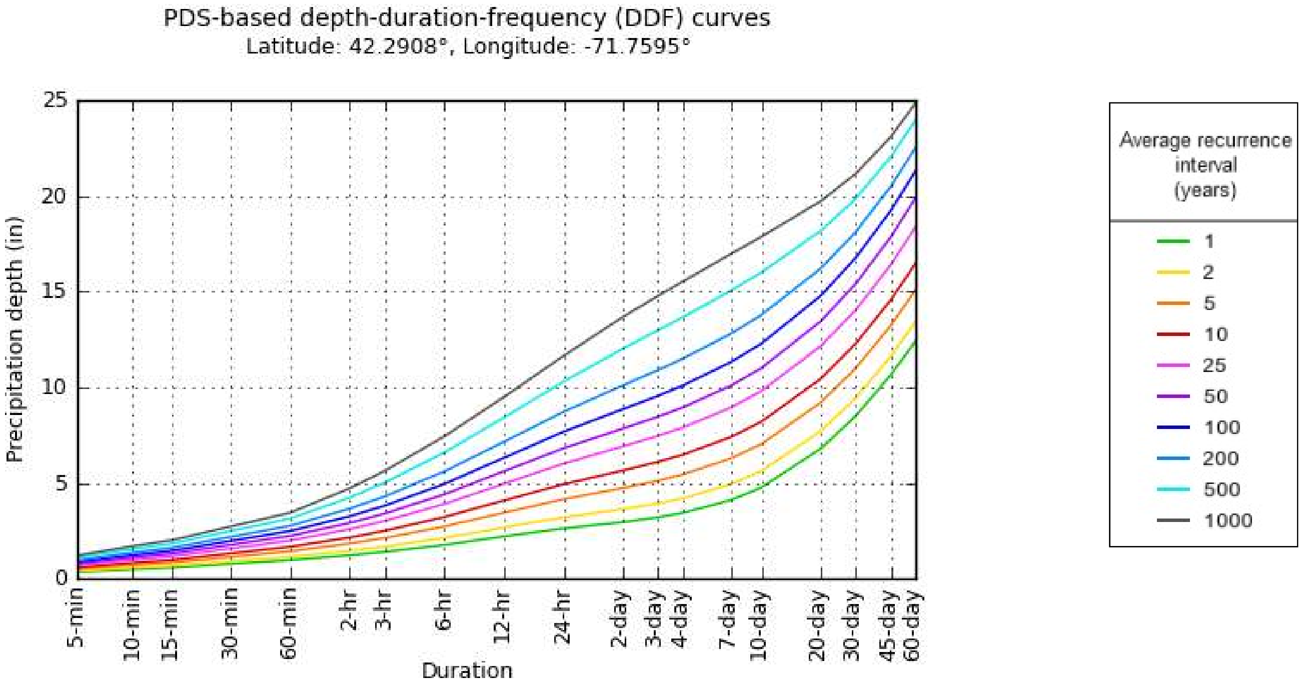
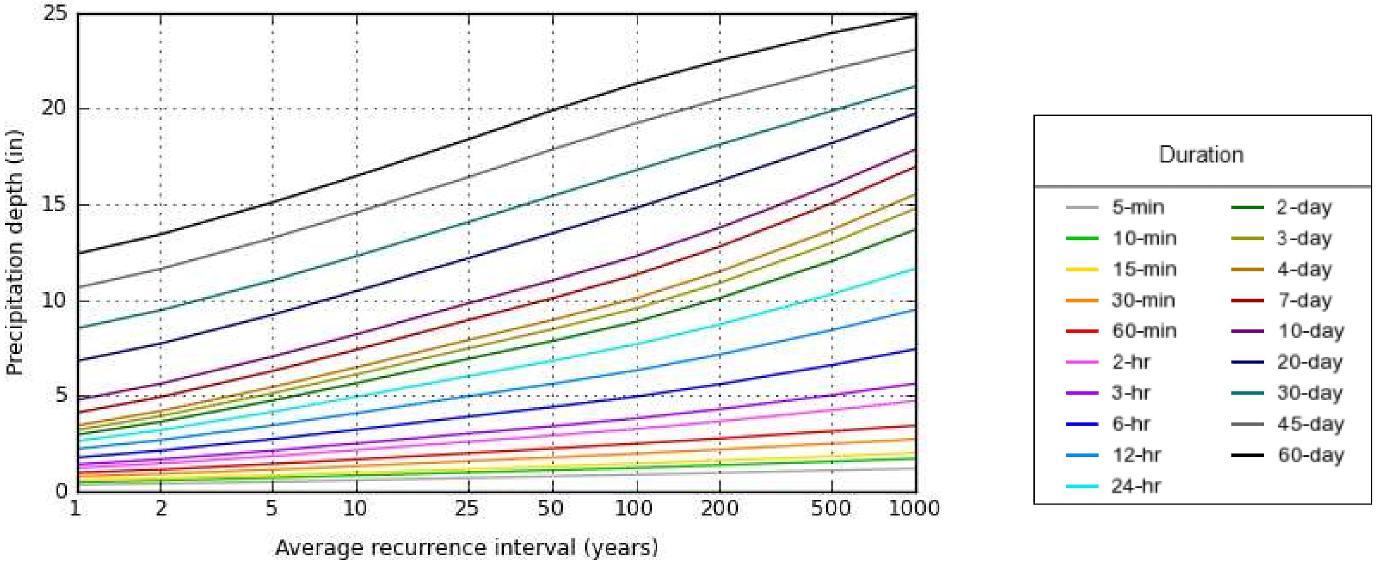
PF graphical





NOAA Atlas 14, Volume 10, Version 3

Created (GMT): Tue Jun 15 16:54:39 2021

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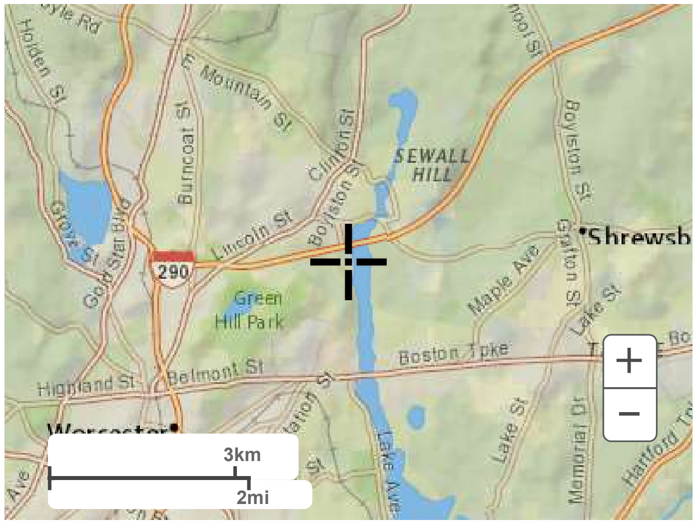
Maps & aerials

Small scale terrain



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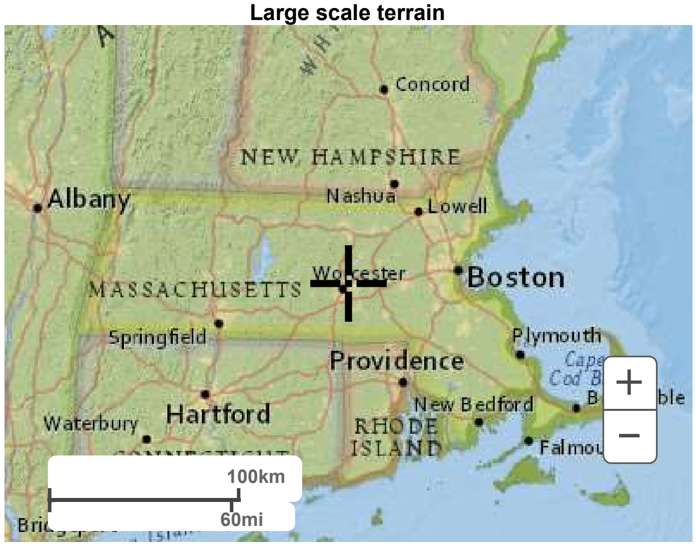
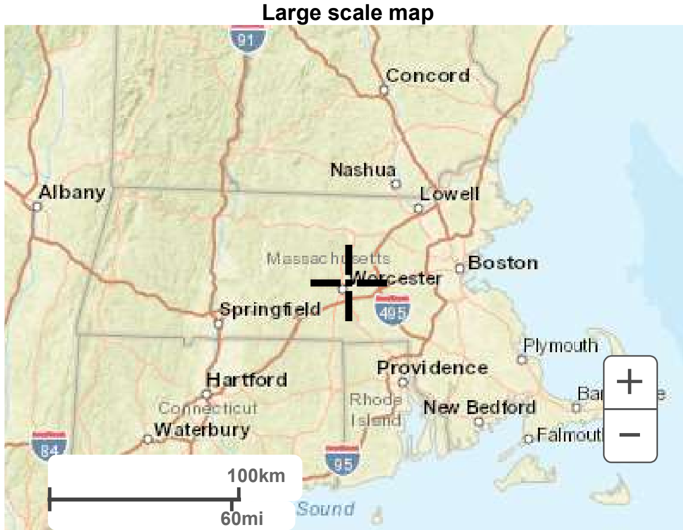


Large scale map



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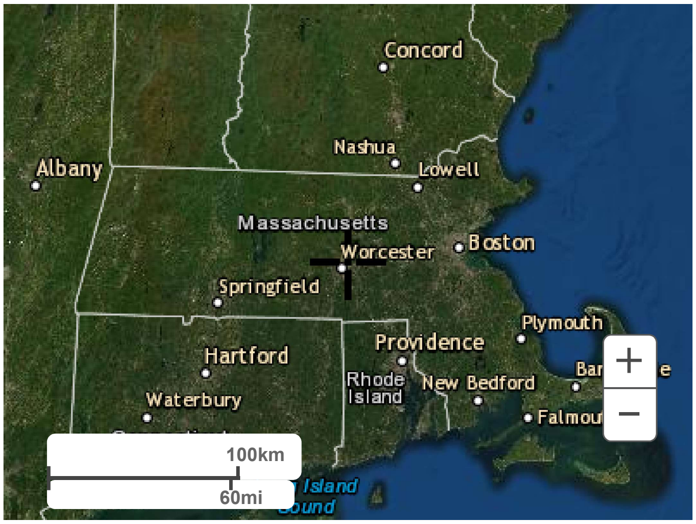

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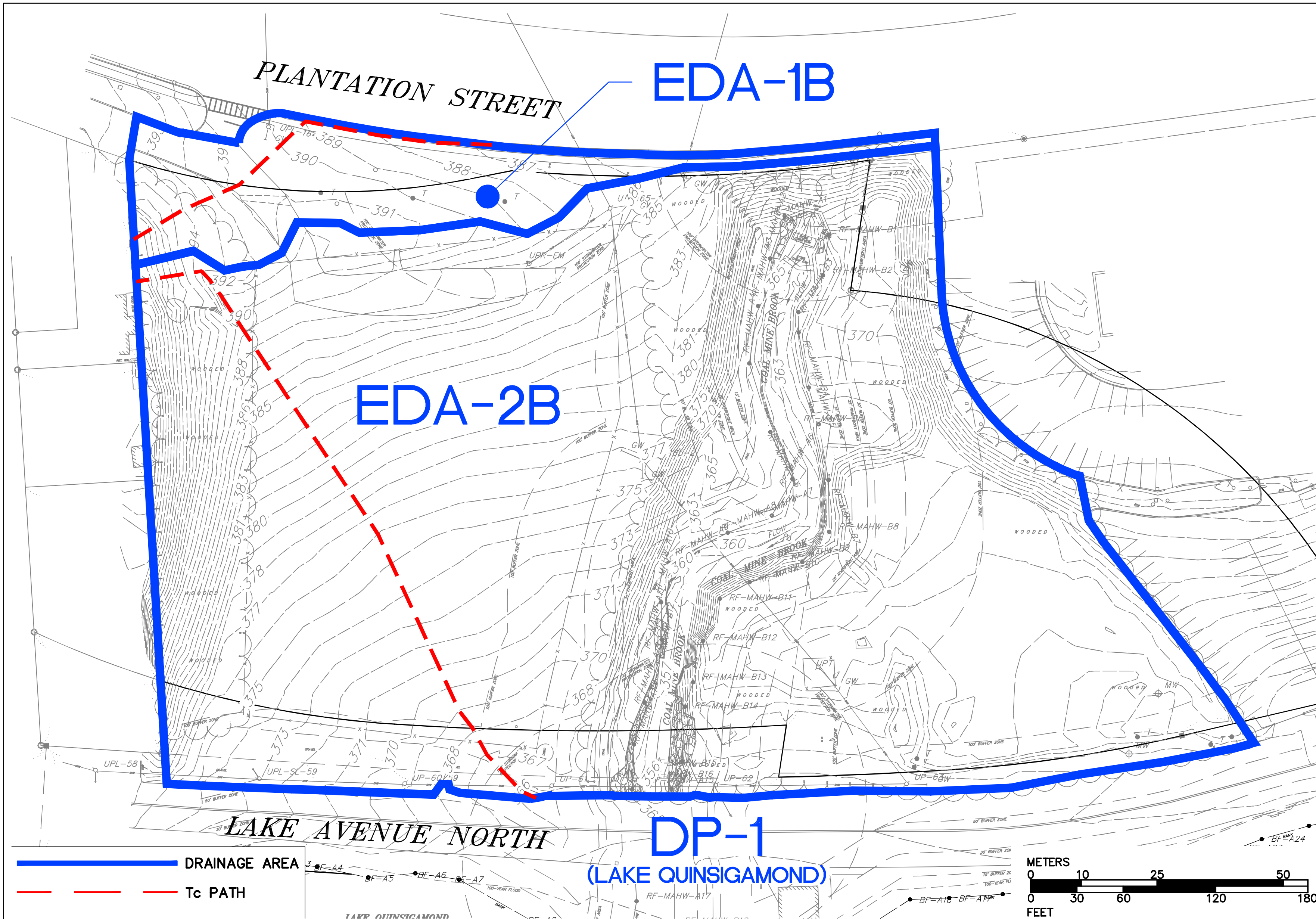
US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer



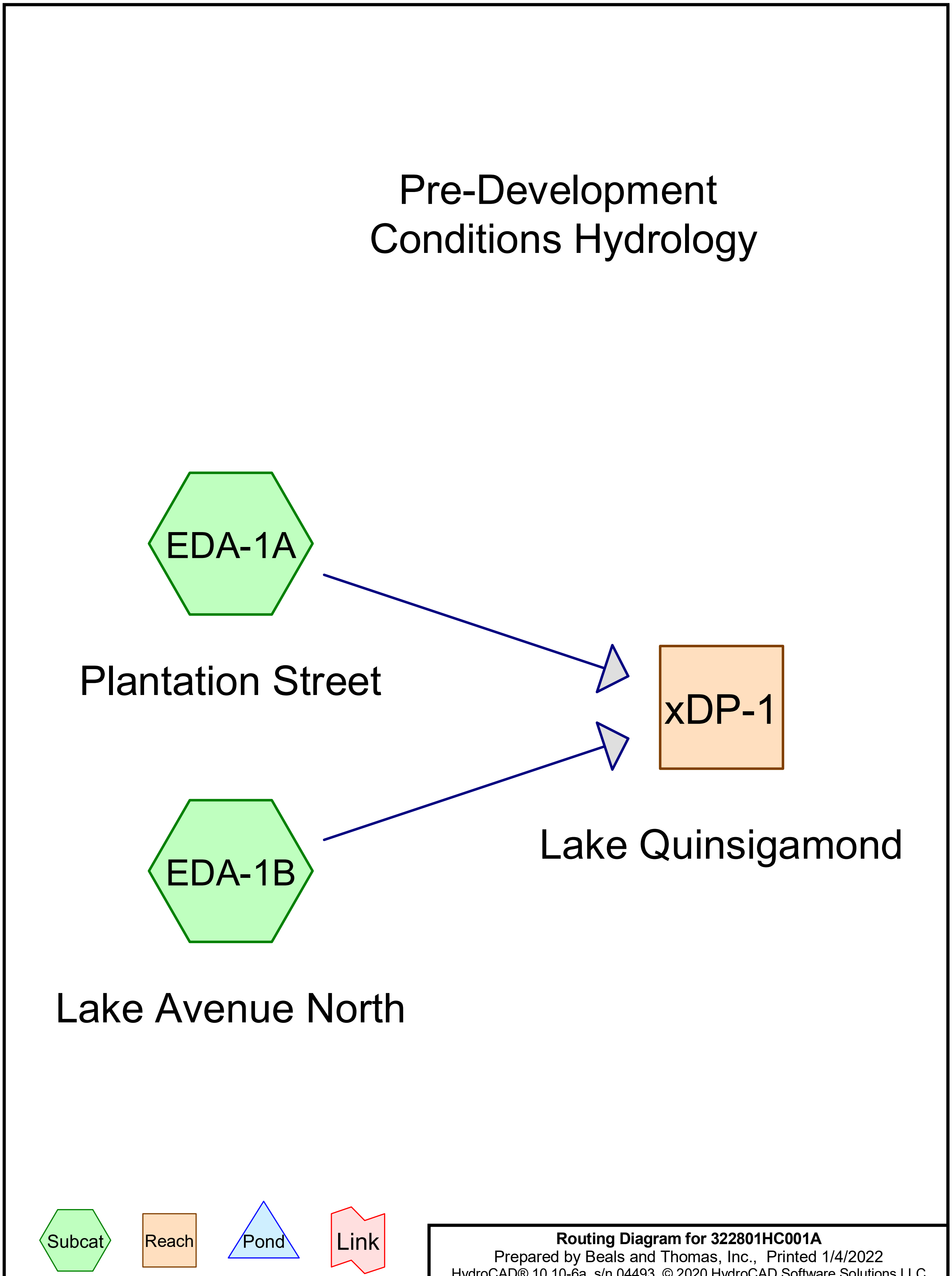
Pre-Development Conditions
Hydrologic Areas Map
Figure Number 001

Scale: 1" = 60'
Date: 01/03/2022
Plan No. 322801P004A-001
B+T Project No. 3228.01

Coal Mine Brook
616 Plantation Street
Worcester, Massachusetts

City of Worcester
50 Skyline Drive
Worcester, Massachusetts

BEALS AND THOMAS, INC.



Routing Diagram for 322801HC001A
Prepared by Beals and Thomas, Inc., Printed 1/4/2022
HydroCAD® 10.10-6a s/n 04493 © 2020 HydroCAD Software Solutions LLC

Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	NOAA-002yr	Type III 24-hr		Default	24.00	1	3.20	2
2	NOAA-010yr	Type III 24-hr		Default	24.00	1	4.93	2
3	NOAA-025yr	Type III 24-hr		Default	24.00	1	6.01	2
4	NOAA-100yr	Type III 24-hr		Default	24.00	1	7.68	2

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
0.595	39	>75% Grass cover, Good, HSG A (EDA-1A, EDA-1B)
1.783	35	Brush, Fair, HSG A (EDA-1B)
0.238	96	Existing Gravel surface, HSG A (EDA-1B)
0.225	98	Existing Impervious, HSG A (EDA-1A, EDA-1B)
0.279	98	Water Surface, HSG A (EDA-1B)
2.599	30	Woods, Good, HSG A (EDA-1A, EDA-1B)
5.719	**41**	**TOTAL AREA**

Time span=1.00-36.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment EDA-1A: Plantation Street Runoff Area=0.507 ac 22.68% Impervious Runoff Depth=0.17"
Tc=6.0 min CN=52 Runoff=0.03 cfs 0.007 af

Subcatchment EDA-1B: Lake Avenue North Runoff Area=5.212 ac 7.46% Impervious Runoff Depth=0.00"
Tc=6.0 min CN=40 Runoff=0.00 cfs 0.001 af

Reach xDP-1: Lake Quinsigamond Inflow=0.03 cfs 0.008 af
Outflow=0.03 cfs 0.008 af

Total Runoff Area = 5.719 ac Runoff Volume = 0.008 af Average Runoff Depth = 0.02"
91.19% Pervious = 5.215 ac 8.81% Impervious = 0.504 ac

Summary for Subcatchment EDA-1A: Plantation Street

Runoff = 0.03 cfs @ 12.41 hrs, Volume= 0.007 af, Depth= 0.17"
Routed to Reach xDP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-002yr Rainfall=3.20"

	Area (ac)	CN	Description
	0.048	30	Woods, Good, HSG A
	0.344	39	>75% Grass cover, Good, HSG A
*	0.115	98	Existing Impervious, HSG A
	0.507	52	Weighted Average
	0.392		77.32% Pervious Area
	0.115		22.68% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Subcatchment EDA-1B: Lake Avenue North

Runoff = 0.00 cfs @ 23.95 hrs, Volume= 0.001 af, Depth= 0.00"
Routed to Reach xDP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-002yr Rainfall=3.20"

	Area (ac)	CN	Description
	2.551	30	Woods, Good, HSG A
	1.783	35	Brush, Fair, HSG A
	0.251	39	>75% Grass cover, Good, HSG A
*	0.238	96	Existing Gravel surface, HSG A
*	0.110	98	Existing Impervious, HSG A
	0.279	98	Water Surface, HSG A
	5.212	40	Weighted Average
	4.823		92.54% Pervious Area
	0.389		7.46% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Reach xDP-1: Lake Quinsigamond

Inflow Area = 5.719 ac, 8.81% Impervious, Inflow Depth = 0.02" for NOAA-002yr event
Inflow = 0.03 cfs @ 12.41 hrs, Volume= 0.008 af
Outflow = 0.03 cfs @ 12.41 hrs, Volume= 0.008 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs

Time span=1.00-36.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment EDA-1A: Plantation Street Runoff Area=0.507 ac 22.68% Impervious Runoff Depth=0.77"
Tc=6.0 min CN=52 Runoff=0.32 cfs 0.033 af

Subcatchment EDA-1B: Lake Avenue North Runoff Area=5.212 ac 7.46% Impervious Runoff Depth=0.22"
Tc=6.0 min CN=40 Runoff=0.26 cfs 0.096 af

Reach xDP-1: Lake Quinsigamond Inflow=0.43 cfs 0.128 af
Outflow=0.43 cfs 0.128 af

Total Runoff Area = 5.719 ac Runoff Volume = 0.128 af Average Runoff Depth = 0.27"
91.19% Pervious = 5.215 ac 8.81% Impervious = 0.504 ac

Summary for Subcatchment EDA-1A: Plantation Street

Runoff = 0.32 cfs @ 12.12 hrs, Volume= 0.033 af, Depth= 0.77"
Routed to Reach xDP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-010yr Rainfall=4.93"

	Area (ac)	CN	Description
	0.048	30	Woods, Good, HSG A
	0.344	39	>75% Grass cover, Good, HSG A
*	0.115	98	Existing Impervious, HSG A
	0.507	52	Weighted Average
	0.392		77.32% Pervious Area
	0.115		22.68% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Subcatchment EDA-1B: Lake Avenue North

Runoff = 0.26 cfs @ 12.45 hrs, Volume= 0.096 af, Depth= 0.22"
Routed to Reach xDP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-010yr Rainfall=4.93"

	Area (ac)	CN	Description
	2.551	30	Woods, Good, HSG A
	1.783	35	Brush, Fair, HSG A
	0.251	39	>75% Grass cover, Good, HSG A
*	0.238	96	Existing Gravel surface, HSG A
*	0.110	98	Existing Impervious, HSG A
	0.279	98	Water Surface, HSG A
	5.212	40	Weighted Average
	4.823		92.54% Pervious Area
	0.389		7.46% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Reach xDP-1: Lake Quinsigamond

Inflow Area = 5.719 ac, 8.81% Impervious, Inflow Depth = 0.27" for NOAA-010yr event
Inflow = 0.43 cfs @ 12.41 hrs, Volume= 0.128 af
Outflow = 0.43 cfs @ 12.41 hrs, Volume= 0.128 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs

Time span=1.00-36.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment EDA-1A: Plantation Street Runoff Area=0.507 ac 22.68% Impervious Runoff Depth=1.29"
Tc=6.0 min CN=52 Runoff=0.64 cfs 0.055 af

Subcatchment EDA-1B: Lake Avenue North Runoff Area=5.212 ac 7.46% Impervious Runoff Depth=0.50"
Tc=6.0 min CN=40 Runoff=1.13 cfs 0.218 af

Reach xDP-1: Lake Quinsigamond Inflow=1.50 cfs 0.273 af
Outflow=1.50 cfs 0.273 af

Total Runoff Area = 5.719 ac Runoff Volume = 0.273 af Average Runoff Depth = 0.57"
91.19% Pervious = 5.215 ac 8.81% Impervious = 0.504 ac

Summary for Subcatchment EDA-1A: Plantation Street

Runoff = 0.64 cfs @ 12.11 hrs, Volume= 0.055 af, Depth= 1.29"
Routed to Reach xDP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-025yr Rainfall=6.01"

	Area (ac)	CN	Description
	0.048	30	Woods, Good, HSG A
	0.344	39	>75% Grass cover, Good, HSG A
*	0.115	98	Existing Impervious, HSG A
	0.507	52	Weighted Average
	0.392		77.32% Pervious Area
	0.115		22.68% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Subcatchment EDA-1B: Lake Avenue North

Runoff = 1.13 cfs @ 12.32 hrs, Volume= 0.218 af, Depth= 0.50"
Routed to Reach xDP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-025yr Rainfall=6.01"

	Area (ac)	CN	Description
	2.551	30	Woods, Good, HSG A
	1.783	35	Brush, Fair, HSG A
	0.251	39	>75% Grass cover, Good, HSG A
*	0.238	96	Existing Gravel surface, HSG A
*	0.110	98	Existing Impervious, HSG A
	0.279	98	Water Surface, HSG A
	5.212	40	Weighted Average
	4.823		92.54% Pervious Area
	0.389		7.46% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Reach xDP-1: Lake Quinsigamond

Inflow Area = 5.719 ac, 8.81% Impervious, Inflow Depth = 0.57" for NOAA-025yr event
Inflow = 1.50 cfs @ 12.28 hrs, Volume= 0.273 af
Outflow = 1.50 cfs @ 12.28 hrs, Volume= 0.273 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs

Time span=1.00-36.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment EDA-1A: Plantation Street Runoff Area=0.507 ac 22.68% Impervious Runoff Depth=2.26"
Tc=6.0 min CN=52 Runoff=1.23 cfs 0.095 af

Subcatchment EDA-1B: Lake Avenue North Runoff Area=5.212 ac 7.46% Impervious Runoff Depth=1.11"
Tc=6.0 min CN=40 Runoff=4.38 cfs 0.483 af

Reach xDP-1: Lake Quinsigamond Inflow=5.58 cfs 0.579 af
Outflow=5.58 cfs 0.579 af

Total Runoff Area = 5.719 ac Runoff Volume = 0.579 af Average Runoff Depth = 1.21"
91.19% Pervious = 5.215 ac 8.81% Impervious = 0.504 ac

Summary for Subcatchment EDA-1A: Plantation Street

Runoff = 1.23 cfs @ 12.10 hrs, Volume= 0.095 af, Depth= 2.26"
Routed to Reach xDP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-100yr Rainfall=7.68"

	Area (ac)	CN	Description
	0.048	30	Woods, Good, HSG A
	0.344	39	>75% Grass cover, Good, HSG A
*	0.115	98	Existing Impervious, HSG A
	0.507	52	Weighted Average
	0.392		77.32% Pervious Area
	0.115		22.68% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Subcatchment EDA-1B: Lake Avenue North

Runoff = 4.38 cfs @ 12.12 hrs, Volume= 0.483 af, Depth= 1.11"
Routed to Reach xDP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-100yr Rainfall=7.68"

	Area (ac)	CN	Description
	2.551	30	Woods, Good, HSG A
	1.783	35	Brush, Fair, HSG A
	0.251	39	>75% Grass cover, Good, HSG A
*	0.238	96	Existing Gravel surface, HSG A
*	0.110	98	Existing Impervious, HSG A
	0.279	98	Water Surface, HSG A
	5.212	40	Weighted Average
	4.823		92.54% Pervious Area
	0.389		7.46% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Reach xDP-1: Lake Quinsigamond

Inflow Area = 5.719 ac, 8.81% Impervious, Inflow Depth = 1.21" for NOAA-100yr event
Inflow = 5.58 cfs @ 12.12 hrs, Volume= 0.579 af
Outflow = 5.58 cfs @ 12.12 hrs, Volume= 0.579 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs

Attachment 3
Post-Development Hydrologic Analysis

POST-DEVELOPMENT CONDITIONS HYDROLOGY CALCULATION SUMMARY

OBJECTIVE
To determine the post-development peak rates of runoff from the site for the 2, 10, 25, & 100-year storm events at the design points.

CONCLUSION(S)
Peak Runoff Rates (CFS):

Storm Event	DP-1
2-Year	0.03
10-Year	0.34
25-Year	1.13
100-Year	4.73

Conclusion: Overall runoff rates from the project area will be less than existing conditions in accordance with Standard 2 of the MassDEP Stormwater Management Regulations

CALCULATION METHODS
1. Runoff curve numbers (CN), time-of-concentration (Tc), and runoff rates were calculated based on TR-55 methodology.
2. AutoCAD 2019 computer program was utilized for digitizing ground cover areas.
3. Peak runoff runoff rates were computed using HydroCAD version 10.10.
4. Design storms calculated using NOAA Atlas 14 point precipitation frequency estimates.

ASSUMPTIONS
1. The ground cover types were determined using aerial imagery. Hydrologic soil groups based on United States Department of Agriculture, NRCS Soil Survey map information.
2. Stormwater runoff from offsite tributary areas was included in the calculations.

SOURCES OF DATA/ EQUATIONS
1. Post-Development Conditions Hydrologic Areas Map prepared by Beals and Thomas, Inc. File No. 322801P004A-002.
2. NRCS Soil Survey for Worcester County, downloaded from Web Soil Survey on 05/18/2021.
3. TR-55 urban Hydrology for Small Watersheds, SCS, 1986.
4. Massachusetts DEP Stormwater Management Handbook, February 2008.

REV	CALC. BY	DATE	CHECKED BY	DATE	APPROVED BY	DATE
0	NBB	01/03/2022	DMG	01/03/2022	DMG	01/04/2022

NBB/322801CS002

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NOAA Atlas 14, Volume 10, Version 3
Location name: Worcester, Massachusetts, USA*
Latitude: 42.2908°, Longitude: -71.7595°
Elevation: 363.65 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.345** (0.272-0.432)	**0.405** (0.319-0.508)	**0.504** (0.396-0.635)	**0.586** (0.457-0.742)	**0.699** (0.526-0.925)	**0.785** (0.577-1.06)	**0.873** (0.621-1.23)	**0.968** (0.655-1.40)	**1.10** (0.715-1.66)	**1.21** (0.763-1.86)
10-min	**0.489** (0.385-0.612)	**0.574** (0.452-0.720)	**0.714** (0.560-0.899)	**0.830** (0.648-1.05)	**0.990** (0.745-1.31)	**1.11** (0.818-1.51)	**1.24** (0.880-1.74)	**1.37** (0.928-1.99)	**1.56** (1.01-2.35)	**1.71** (1.08-2.63)
15-min	**0.575** (0.453-0.720)	**0.675** (0.532-0.847)	**0.840** (0.659-1.06)	**0.977** (0.762-1.24)	**1.17** (0.877-1.54)	**1.31** (0.962-1.77)	**1.46** (1.03-2.04)	**1.61** (1.09-2.34)	**1.83** (1.19-2.76)	**2.01** (1.27-3.09)
30-min	**0.776** (0.612-0.972)	**0.913** (0.719-1.15)	**1.14** (0.892-1.43)	**1.32** (1.03-1.68)	**1.58** (1.19-2.09)	**1.77** (1.31-2.40)	**1.97** (1.40-2.77)	**2.19** (1.48-3.17)	**2.49** (1.62-3.75)	**2.73** (1.73-4.20)
60-min	**0.977** (0.770-1.22)	**1.15** (0.906-1.44)	**1.43** (1.13-1.80)	**1.67** (1.30-2.11)	**1.99** (1.50-2.64)	**2.24** (1.65-3.03)	**2.49** (1.77-3.50)	**2.77** (1.87-4.01)	**3.14** (2.04-4.73)	**3.45** (2.18-5.30)
2-hr	**1.23** (0.973-1.53)	**1.46** (1.16-1.82)	**1.84** (1.45-2.30)	**2.16** (1.69-2.72)	**2.59** (1.97-3.42)	**2.92** (2.17-3.95)	**3.26** (2.35-4.60)	**3.66** (2.48-5.27)	**4.24** (2.76-6.35)	**4.73** (3.00-7.23)
3-hr	**1.40** (1.12-1.74)	**1.68** (1.34-2.08)	**2.13** (1.69-2.65)	**2.50** (1.97-3.14)	**3.02** (2.30-3.98)	**3.40** (2.54-4.60)	**3.81** (2.76-5.38)	**4.30** (2.92-6.17)	**5.02** (3.28-7.49)	**5.63** (3.58-8.58)
6-hr	**1.77** (1.42-2.18)	**2.13** (1.71-2.63)	**2.73** (2.18-3.38)	**3.22** (2.55-4.01)	**3.90** (2.99-5.12)	**4.41** (3.31-5.93)	**4.95** (3.61-6.96)	**5.60** (3.82-8.00)	**6.59** (4.31-9.76)	**7.43** (4.74-11.2)
12-hr	**2.21** (1.78-2.71)	**2.68** (2.16-3.29)	**3.45** (2.77-4.25)	**4.09** (3.26-5.06)	**4.96** (3.83-6.47)	**5.61** (4.24-7.50)	**6.31** (4.63-8.81)	**7.15** (4.90-10.1)	**8.42** (5.52-12.4)	**9.49** (6.07-14.3)
24-hr	**2.63** (2.13-3.20)	**3.20** (2.60-3.91)	**4.15** (3.36-5.08)	**4.93** (3.96-6.07)	**6.01** (4.67-7.80)	**6.81** (5.18-9.06)	**7.68** (5.66-10.7)	**8.72** (5.99-12.3)	**10.3** (6.78-15.1)	**11.6** (7.47-17.4)
2-day	**2.96** (2.42-3.58)	**3.63** (2.97-4.40)	**4.74** (3.86-5.76)	**5.65** (4.57-6.92)	**6.92** (5.40-8.92)	**7.85** (6.00-10.4)	**8.86** (6.58-12.3)	**10.1** (6.97-14.2)	**12.0** (7.94-17.5)	**13.7** (8.81-20.3)
3-day	**3.21** (2.63-3.87)	**3.93** (3.23-4.75)	**5.12** (4.18-6.20)	**6.11** (4.96-7.44)	**7.46** (5.85-9.59)	**8.46** (6.50-11.2)	**9.55** (7.12-13.2)	**10.9** (7.54-15.2)	**13.0** (8.59-18.8)	**14.8** (9.53-21.8)
4-day	**3.44** (2.83-4.14)	**4.20** (3.46-5.06)	**5.44** (4.46-6.58)	**6.48** (5.27-7.87)	**7.90** (6.21-10.1)	**8.94** (6.88-11.8)	**10.1** (7.53-13.9)	**11.5** (7.96-16.0)	**13.7** (9.05-19.7)	**15.5** (10.0-22.9)
7-day	**4.11** (3.40-4.91)	**4.93** (4.08-5.90)	**6.28** (5.17-7.55)	**7.40** (6.05-8.95)	**8.94** (7.05-11.4)	**10.1** (7.77-13.1)	**11.3** (8.45-15.4)	**12.8** (8.90-17.7)	**15.0** (10.0-21.6)	**17.0** (11.0-24.8)
10-day	**4.77** (3.96-5.68)	**5.63** (4.67-6.72)	**7.03** (5.82-8.43)	**8.20** (6.74-9.89)	**9.81** (7.76-12.4)	**11.0** (8.50-14.3)	**12.3** (9.17-16.6)	**13.8** (9.62-19.0)	**16.0** (10.7-22.9)	**17.9** (11.6-26.1)
20-day	**6.81** (5.70-8.06)	**7.72** (6.46-9.16)	**9.22** (7.67-11.0)	**10.5** (8.65-12.5)	**12.2** (9.66-15.2)	**13.5** (10.4-17.2)	**14.8** (11.0-19.6)	**16.2** (11.4-22.1)	**18.2** (12.2-25.8)	**19.7** (12.8-28.6)
30-day	**8.51** (7.16-10.0)	**9.46** (7.94-11.2)	**11.0** (9.20-13.1)	**12.3** (10.2-14.7)	**14.1** (11.2-17.4)	**15.4** (11.9-19.5)	**16.8** (12.4-21.9)	**18.1** (12.8-24.6)	**19.9** (13.4-28.0)	**21.2** (13.8-30.6)
45-day	**10.6** (8.98-12.5)	**11.6** (9.79-13.7)	**13.2** (11.1-15.6)	**14.6** (12.1-17.3)	**16.4** (13.1-20.2)	**17.8** (13.8-22.4)	**19.2** (14.2-24.9)	**20.5** (14.5-27.7)	**22.0** (14.9-30.9)	**23.1** (15.1-33.2)
60-day	**12.4** (10.5-14.5)	**13.4** (11.3-15.8)	**15.1** (12.7-17.8)	**16.5** (13.8-19.5)	**18.4** (14.7-22.5)	**19.9** (15.4-24.8)	**21.3** (15.8-27.4)	**22.5** (16.0-30.3)	**23.9** (16.2-33.5)	**24.8** (16.3-35.6)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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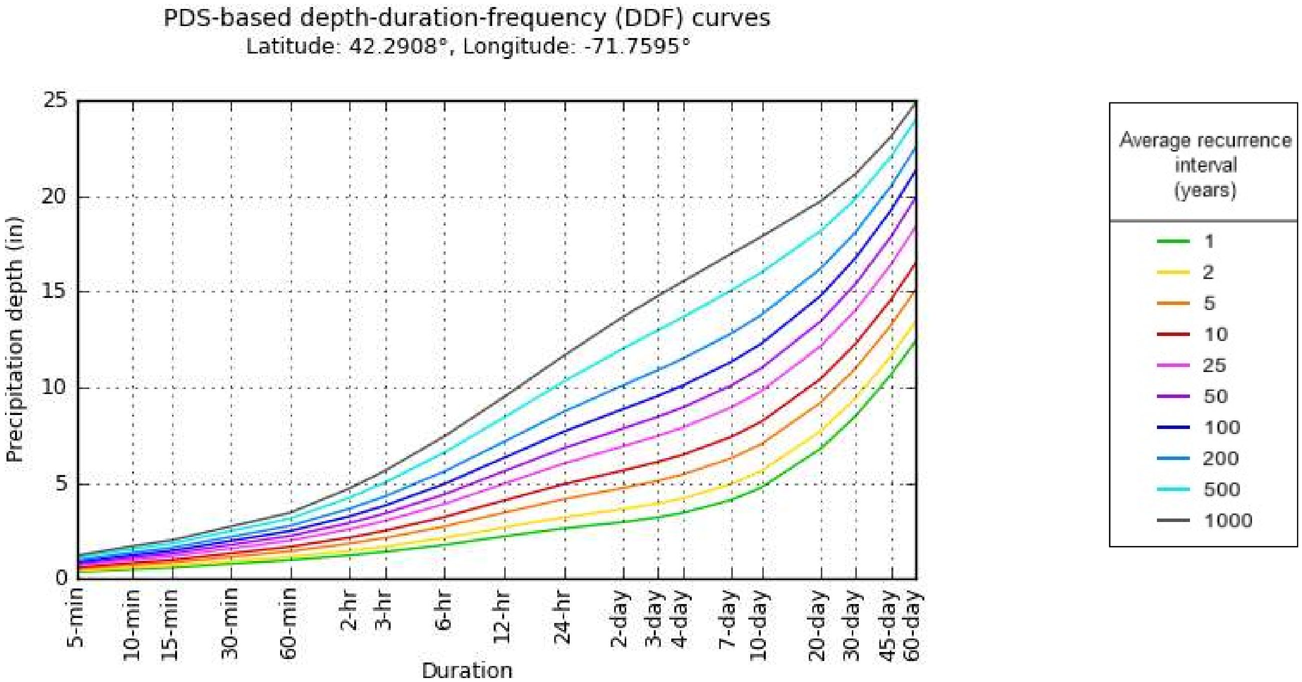
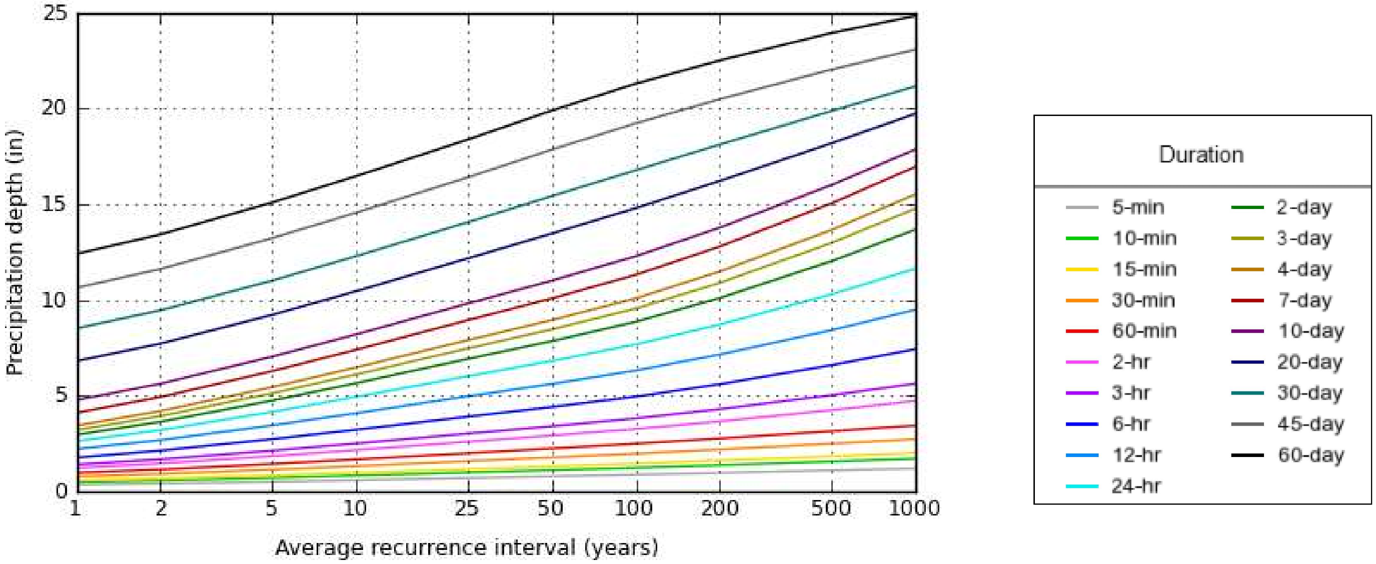
PF graphical





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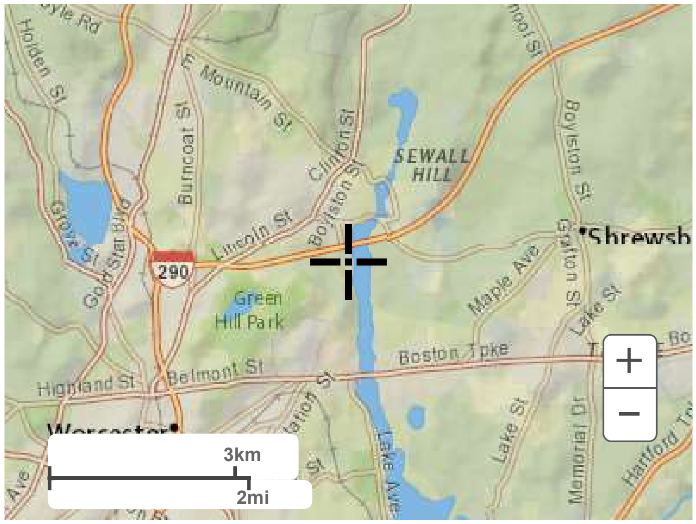
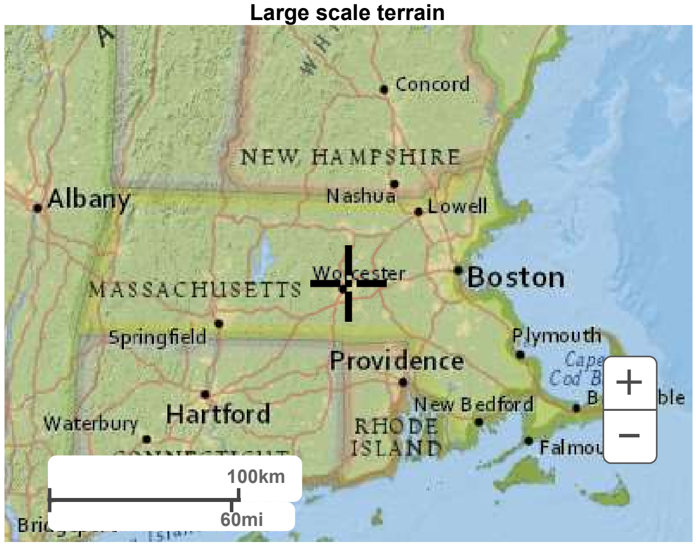
Maps & aerials

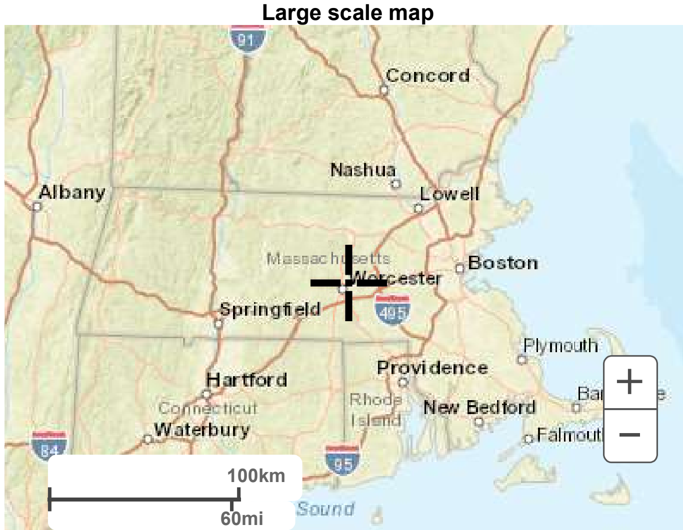
Small scale terrain



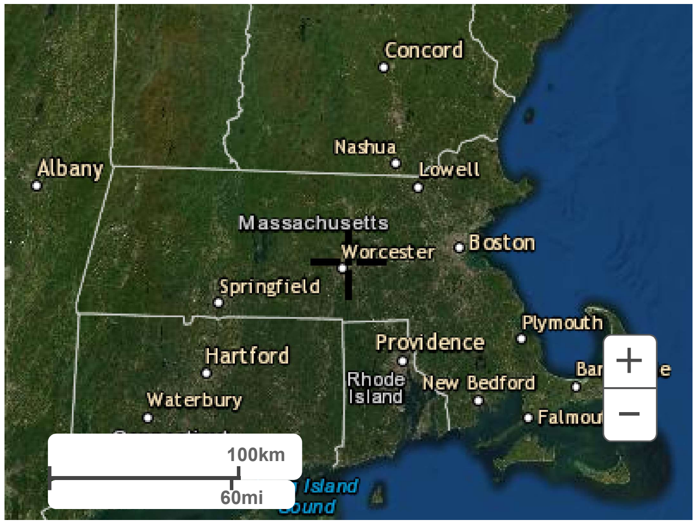
Large scale terrain



Large scale map



Large scale aerial



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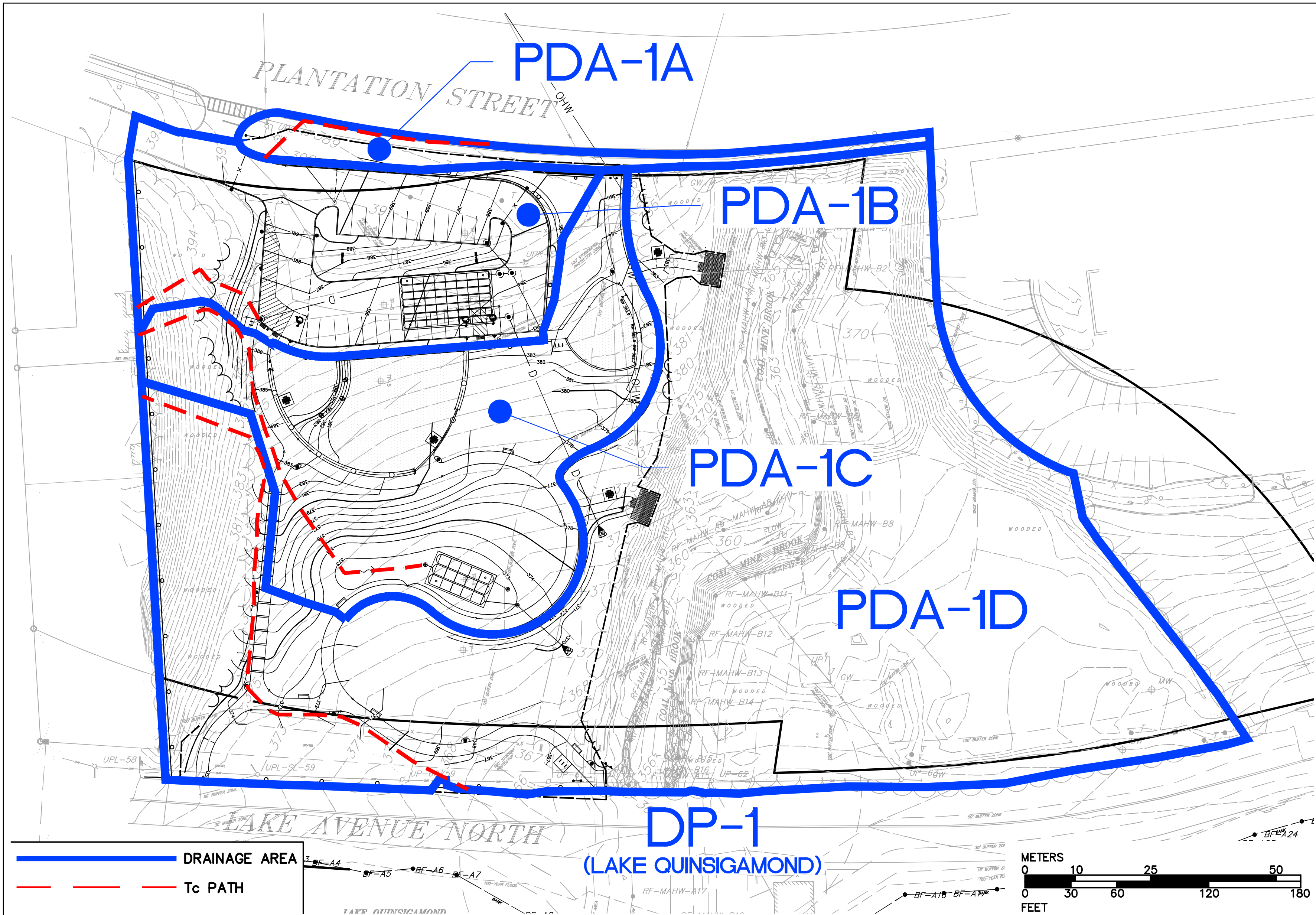
US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer



Post–Development Conditions
Hydrologic Areas Map
Figure Number 002

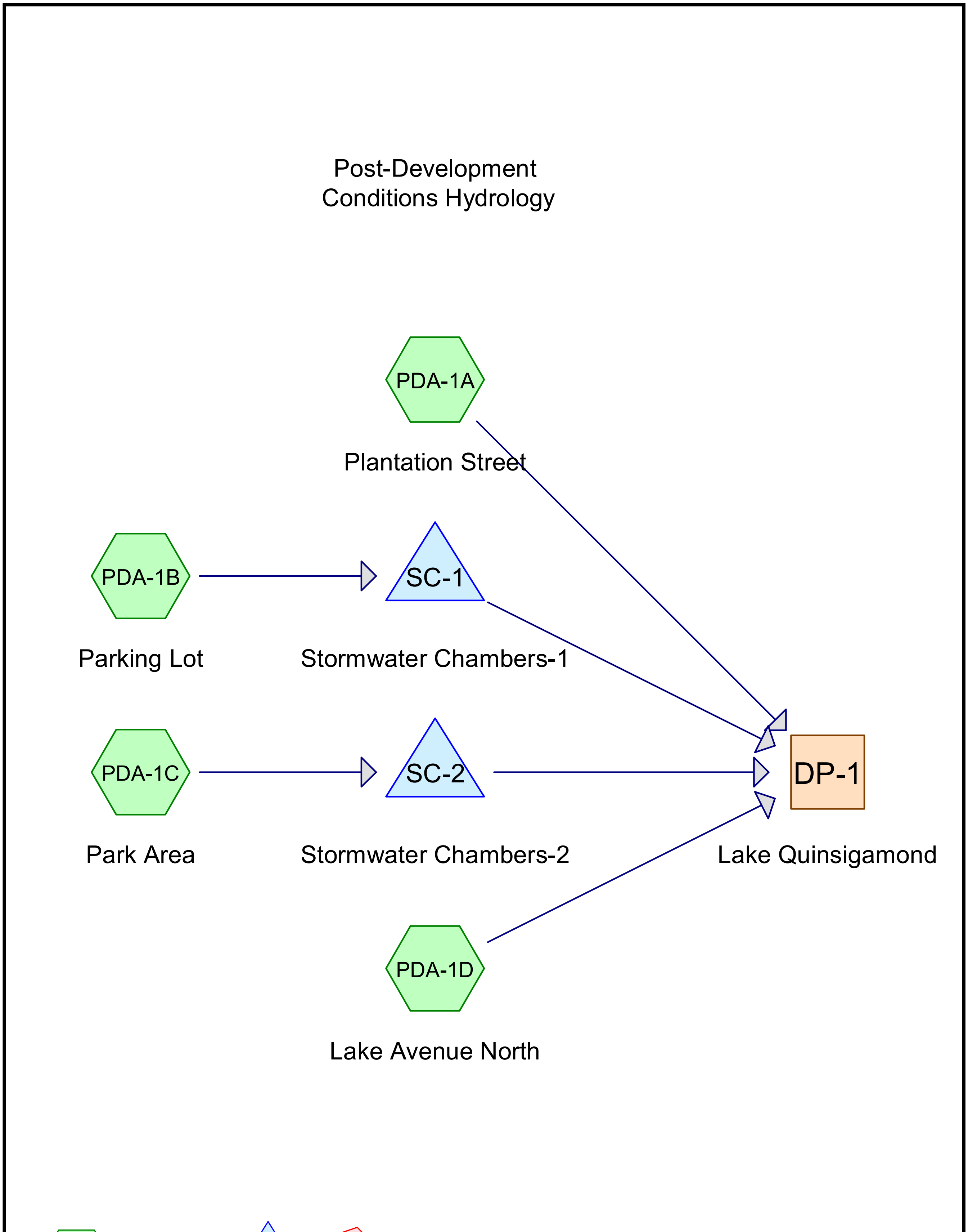
Scale: 1" = 60'
Date: 01/03/2022
Plan No. 322801P004A–002
B+T Project No. 3228.01

Coal Mine Brook
616 Plantation Street
Worcester, Massachusetts

City of Worcester
50 Skyline Drive
Worcester, Massachusetts

North Arrow
NORTH

BEALS AND THOMAS, INC.



Routing Diagram for 322801HC001A
Prepared by Beals and Thomas, Inc., Printed 1/4/2022
HydroCAD® 10.10-6a s/n 04493 © 2020 HydroCAD Software Solutions LLC

Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	NOAA-002yr	Type III 24-hr		Default	24.00	1	3.20	2
2	NOAA-010yr	Type III 24-hr		Default	24.00	1	4.93	2
3	NOAA-025yr	Type III 24-hr		Default	24.00	1	6.01	2
4	NOAA-100yr	Type III 24-hr		Default	24.00	1	7.68	2

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
1.767	39	>75% Grass cover, Good, HSG A (PDA-1A, PDA-1B, PDA-1C, PDA-1D)
0.088	96	Existing Gravel surface, HSG A (PDA-1D)
0.084	98	Existing Impervious, HSG A (PDA-1A, PDA-1B, PDA-1D)
0.398	98	Paved Parking, HSG A (PDA-1B)
0.281	98	Permeable Pavement, HSG A (PDA-1B, PDA-1C, PDA-1D)
0.215	39	Playground Area, HSG A (PDA-1C)
0.061	98	Proposed Impervious, HSG A (PDA-1A, PDA-1B, PDA-1C, PDA-1D)
0.077	39	Turf, HSG A (PDA-1B)
0.279	98	Water Surface, HSG A (PDA-1D)
2.469	30	Woods, Good, HSG A (PDA-1B, PDA-1C, PDA-1D)
5.719	**47**	**TOTAL AREA**

Time span=1.00-36.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment PDA-1A: Plantation Street Runoff Area=0.150 ac 32.67% Impervious Runoff Depth=0.34"
Tc=6.0 min CN=58 Runoff=0.03 cfs 0.004 af

Subcatchment PDA-1B: Parking Lot Runoff Area=0.769 ac 59.69% Impervious Runoff Depth=0.98"
Tc=6.0 min CN=73 Runoff=0.82 cfs 0.063 af

Subcatchment PDA-1C: Park Area Runoff Area=1.092 ac 18.50% Impervious Runoff Depth=0.13"
Tc=6.0 min CN=50 Runoff=0.03 cfs 0.012 af

Subcatchment PDA-1D: Lake Avenue North Runoff Area=3.708 ac 10.60% Impervious Runoff Depth=0.01"
Tc=6.0 min CN=41 Runoff=0.00 cfs 0.002 af

Reach DP-1: Lake Quinsigamond Inflow=0.03 cfs 0.006 af
Outflow=0.03 cfs 0.006 af

Pond SC-1: Stormwater Chambers-1 Peak Elev=379.02' Storage=0.017 af Inflow=0.82 cfs 0.063 af
Discarded=0.16 cfs 0.063 af Primary=0.00 cfs 0.000 af Outflow=0.16 cfs 0.063 af

Pond SC-2: Stormwater Chambers-2 Peak Elev=367.02' Storage=0.000 af Inflow=0.03 cfs 0.012 af
Discarded=0.02 cfs 0.012 af Primary=0.00 cfs 0.000 af Outflow=0.02 cfs 0.012 af

Total Runoff Area = 5.719 ac Runoff Volume = 0.081 af Average Runoff Depth = 0.17"
80.71% Pervious = 4.616 ac 19.29% Impervious = 1.103 ac

Summary for Subcatchment PDA-1A: Plantation Street

Runoff = 0.03 cfs @ 12.17 hrs, Volume= 0.004 af, Depth= 0.34"
Routed to Reach DP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-002yr Rainfall=3.20"

	Area (ac)	CN	Description
	0.101	39	>75% Grass cover, Good, HSG A
*	0.048	98	Existing Impervious, HSG A
*	0.001	98	Proposed Impervious, HSG A
	0.150	58	Weighted Average
	0.101		67.33% Pervious Area
	0.049		32.67% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Subcatchment PDA-1B: Parking Lot

Runoff = 0.82 cfs @ 12.10 hrs, Volume= 0.063 af, Depth= 0.98"
Routed to Pond SC-1 : Stormwater Chambers-1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-002yr Rainfall=3.20"

	Area (ac)	CN	Description
	0.075	30	Woods, Good, HSG A
	0.158	39	>75% Grass cover, Good, HSG A
*	0.077	39	Turf, HSG A
*	0.027	98	Permeable Pavement, HSG A
*	0.002	98	Proposed Impervious, HSG A
*	0.032	98	Existing Impervious, HSG A
*	0.398	98	Paved Parking, HSG A
	0.769	73	Weighted Average
	0.310		40.31% Pervious Area
	0.459		59.69% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc. Min**

Summary for Subcatchment PDA-1C: Park Area

Runoff = 0.03 cfs @ 12.48 hrs, Volume= 0.012 af, Depth= 0.13"
Routed to Pond SC-2 : Stormwater Chambers-2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-002yr Rainfall=3.20"

	Area (ac)	CN	Description
	0.050	30	Woods, Good, HSG A
	0.625	39	>75% Grass cover, Good, HSG A
*	0.215	39	Playground Area, HSG A
*	0.166	98	Permeable Pavement, HSG A
*	0.036	98	Proposed Impervious, HSG A
	1.092	50	Weighted Average
	0.890		81.50% Pervious Area
	0.202		18.50% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc. Min**

Summary for Subcatchment PDA-1D: Lake Avenue North

Runoff = 0.00 cfs @ 22.67 hrs, Volume= 0.002 af, Depth= 0.01"
Routed to Reach DP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-002yr Rainfall=3.20"

	Area (ac)	CN	Description
	2.344	30	Woods, Good, HSG A
	0.883	39	>75% Grass cover, Good, HSG A
*	0.088	98	Permeable Pavement, HSG A
*	0.088	96	Existing Gravel surface, HSG A
*	0.022	98	Proposed Impervious, HSG A
*	0.004	98	Existing Impervious, HSG A
	0.279	98	Water Surface, HSG A
	3.708	41	Weighted Average
	3.315		89.40% Pervious Area
	0.393		10.60% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Reach DP-1: Lake Quinsigamond

Inflow Area = 5.719 ac, 19.29% Impervious, Inflow Depth = 0.01" for NOAA-002yr event
Inflow = 0.03 cfs @ 12.17 hrs, Volume= 0.006 af
Outflow = 0.03 cfs @ 12.17 hrs, Volume= 0.006 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs

Summary for Pond SC-1: Stormwater Chambers-1

Inflow Area = 0.769 ac, 59.69% Impervious, Inflow Depth = 0.98" for NOAA-002yr event
Inflow = 0.82 cfs @ 12.10 hrs, Volume= 0.063 af
Outflow = 0.16 cfs @ 12.61 hrs, Volume= 0.063 af, Atten= 81%, Lag= 30.7 min
Discarded = 0.16 cfs @ 12.61 hrs, Volume= 0.063 af
Primary = 0.00 cfs @ 1.00 hrs, Volume= 0.000 af
Routed to Reach DP-1 : Lake Quinsigamond

Routing by Stor-Ind method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 379.02' @ 12.61 hrs Surf.Area= 0.048 ac Storage= 0.017 af

Plug-Flow detention time= 36.0 min calculated for 0.063 af (100% of inflow)
Center-of-Mass det. time= 36.0 min (901.4 - 865.4)

Volume	Invert	Avail.Storage	Storage Description
#1A	378.33'	0.044 af	**34.75'W x 60.58'L x 3.50'H Field A** 0.169 af Overall - 0.059 af Embedded = 0.110 af x 40.0% Voids
#2A	378.83'	0.059 af	**ADS_StormTech SC-740 +Cap** x 56 Inside #1 Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap 56 Chambers in 7 Rows
		0.103 af	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Discarded	378.33'	**2.410 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 376.33'
#2	Primary	380.33'	**12.0" Round Culvert** L= 8.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 380.33' / 380.25' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Discarded OutFlow Max=0.16 cfs @ 12.61 hrs HW=379.02' (Free Discharge)
└─**1=Exfiltration** (Controls 0.16 cfs)

Primary OutFlow Max=0.00 cfs @ 1.00 hrs HW=378.33' (Free Discharge)
└─**2=Culvert** (Controls 0.00 cfs)

Summary for Pond SC-2: Stormwater Chambers-2

Inflow Area = 1.092 ac, 18.50% Impervious, Inflow Depth = 0.13" for NOAA-002yr event
Inflow = 0.03 cfs @ 12.48 hrs, Volume= 0.012 af
Outflow = 0.02 cfs @ 12.57 hrs, Volume= 0.012 af, Atten= 11%, Lag= 5.4 min
Discarded = 0.02 cfs @ 12.57 hrs, Volume= 0.012 af
Primary = 0.00 cfs @ 1.00 hrs, Volume= 0.000 af
Routed to Reach DP-1 : Lake Quinsigamond

Routing by Stor-Ind method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 367.02' @ 12.57 hrs Surf.Area= 0.022 ac Storage= 0.000 af

Plug-Flow detention time= 4.9 min calculated for 0.012 af (100% of inflow)
Center-of-Mass det. time= 4.9 min (1,014.8 - 1,010.0)

Volume	Invert	Avail.Storage	Storage Description
#1A	367.00'	0.024 af	**22.75'W x 41.55'L x 5.50'H Field A** 0.119 af Overall - 0.040 af Embedded = 0.079 af x 30.0% Voids
#2A	367.75'	0.040 af	**ADS_StormTech MC-3500 d +Cap** x 15 Inside #1 Effective Size= 70.4"W x 45.0"H => 15.33 sf x 7.17'L = 110.0 cf Overall Size= 77.0"W x 45.0"H x 7.50'L with 0.33' Overlap 15 Chambers in 3 Rows Cap Storage= 14.9 cf x 2 x 3 rows = 89.4 cf
		0.064 af	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Discarded	367.00'	**2.410 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 362.83'
#2	Primary	370.50'	**12.0" Round Culvert** L= 20.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 370.50' / 369.90' S= 0.0300 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Discarded OutFlow Max=0.05 cfs @ 12.57 hrs HW=367.02' (Free Discharge)
└─**1=Exfiltration** (Controls 0.05 cfs)

Primary OutFlow Max=0.00 cfs @ 1.00 hrs HW=367.00' (Free Discharge)
└─**2=Culvert** (Controls 0.00 cfs)

Time span=1.00-36.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment PDA-1A: Plantation Street Runoff Area=0.150 ac 32.67% Impervious Runoff Depth=1.13"
Tc=6.0 min CN=58 Runoff=0.17 cfs 0.014 af

Subcatchment PDA-1B: Parking Lot Runoff Area=0.769 ac 59.69% Impervious Runoff Depth=2.23"
Tc=6.0 min CN=73 Runoff=1.95 cfs 0.143 af

Subcatchment PDA-1C: Park Area Runoff Area=1.092 ac 18.50% Impervious Runoff Depth=0.66"
Tc=6.0 min CN=50 Runoff=0.50 cfs 0.060 af

Subcatchment PDA-1D: Lake Avenue North Runoff Area=3.708 ac 10.60% Impervious Runoff Depth=0.26"
Tc=6.0 min CN=41 Runoff=0.27 cfs 0.079 af

Reach DP-1: Lake Quinsigamond Inflow=0.34 cfs 0.093 af
Outflow=0.34 cfs 0.093 af

Pond SC-1: Stormwater Chambers-1 Peak Elev=380.01' Storage=0.055 af Inflow=1.95 cfs 0.143 af
Discarded=0.22 cfs 0.143 af Primary=0.00 cfs 0.000 af Outflow=0.22 cfs 0.143 af

Pond SC-2: Stormwater Chambers-2 Peak Elev=368.56' Storage=0.019 af Inflow=0.50 cfs 0.060 af
Discarded=0.07 cfs 0.060 af Primary=0.00 cfs 0.000 af Outflow=0.07 cfs 0.060 af

Total Runoff Area = 5.719 ac Runoff Volume = 0.296 af Average Runoff Depth = 0.62"
80.71% Pervious = 4.616 ac 19.29% Impervious = 1.103 ac

Summary for Subcatchment PDA-1A: Plantation Street

Runoff = 0.17 cfs @ 12.11 hrs, Volume= 0.014 af, Depth= 1.13"
Routed to Reach DP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-010yr Rainfall=4.93"

	Area (ac)	CN	Description
	0.101	39	>75% Grass cover, Good, HSG A
*	0.048	98	Existing Impervious, HSG A
*	0.001	98	Proposed Impervious, HSG A
	0.150	58	Weighted Average
	0.101		67.33% Pervious Area
	0.049		32.67% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Subcatchment PDA-1B: Parking Lot

Runoff = 1.95 cfs @ 12.10 hrs, Volume= 0.143 af, Depth= 2.23"
Routed to Pond SC-1 : Stormwater Chambers-1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-010yr Rainfall=4.93"

	Area (ac)	CN	Description
	0.075	30	Woods, Good, HSG A
	0.158	39	>75% Grass cover, Good, HSG A
*	0.077	39	Turf, HSG A
*	0.027	98	Permeable Pavement, HSG A
*	0.002	98	Proposed Impervious, HSG A
*	0.032	98	Existing Impervious, HSG A
*	0.398	98	Paved Parking, HSG A
	0.769	73	Weighted Average
	0.310		40.31% Pervious Area
	0.459		59.69% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc. Min**

Summary for Subcatchment PDA-1C: Park Area

Runoff = 0.50 cfs @ 12.13 hrs, Volume= 0.060 af, Depth= 0.66"
Routed to Pond SC-2 : Stormwater Chambers-2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-010yr Rainfall=4.93"

	Area (ac)	CN	Description
	0.050	30	Woods, Good, HSG A
	0.625	39	>75% Grass cover, Good, HSG A
*	0.215	39	Playground Area, HSG A
*	0.166	98	Permeable Pavement, HSG A
*	0.036	98	Proposed Impervious, HSG A
	1.092	50	Weighted Average
	0.890		81.50% Pervious Area
	0.202		18.50% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc. Min**

Summary for Subcatchment PDA-1D: Lake Avenue North

Runoff = 0.27 cfs @ 12.42 hrs, Volume= 0.079 af, Depth= 0.26"
Routed to Reach DP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-010yr Rainfall=4.93"

	Area (ac)	CN	Description
	2.344	30	Woods, Good, HSG A
	0.883	39	>75% Grass cover, Good, HSG A
*	0.088	98	Permeable Pavement, HSG A
*	0.088	96	Existing Gravel surface, HSG A
*	0.022	98	Proposed Impervious, HSG A
*	0.004	98	Existing Impervious, HSG A
	0.279	98	Water Surface, HSG A
	3.708	41	Weighted Average
	3.315		89.40% Pervious Area
	0.393		10.60% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Reach DP-1: Lake Quinsigamond

Inflow Area = 5.719 ac, 19.29% Impervious, Inflow Depth = 0.20" for NOAA-010yr event
Inflow = 0.34 cfs @ 12.40 hrs, Volume= 0.093 af
Outflow = 0.34 cfs @ 12.40 hrs, Volume= 0.093 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs

Summary for Pond SC-1: Stormwater Chambers-1

Inflow Area = 0.769 ac, 59.69% Impervious, Inflow Depth = 2.23" for NOAA-010yr event
Inflow = 1.95 cfs @ 12.10 hrs, Volume= 0.143 af
Outflow = 0.22 cfs @ 12.99 hrs, Volume= 0.143 af, Atten= 89%, Lag= 53.9 min
Discarded = 0.22 cfs @ 12.99 hrs, Volume= 0.143 af
Primary = 0.00 cfs @ 1.00 hrs, Volume= 0.000 af
Routed to Reach DP-1 : Lake Quinsigamond

Routing by Stor-Ind method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 380.01' @ 12.99 hrs Surf.Area= 0.048 ac Storage= 0.055 af

Plug-Flow detention time= 110.1 min calculated for 0.143 af (100% of inflow)
Center-of-Mass det. time= 110.0 min (950.7 - 840.7)

Volume	Invert	Avail.Storage	Storage Description
#1A	378.33'	0.044 af	**34.75'W x 60.58'L x 3.50'H Field A** 0.169 af Overall - 0.059 af Embedded = 0.110 af x 40.0% Voids
#2A	378.83'	0.059 af	**ADS_StormTech SC-740 +Cap** x 56 Inside #1 Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap 56 Chambers in 7 Rows
		0.103 af	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Discarded	378.33'	**2.410 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 376.33'
#2	Primary	380.33'	**12.0" Round Culvert** L= 8.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 380.33' / 380.25' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Discarded OutFlow Max=0.22 cfs @ 12.99 hrs HW=380.01' (Free Discharge)
└─**1=Exfiltration** (Controls 0.22 cfs)

Primary OutFlow Max=0.00 cfs @ 1.00 hrs HW=378.33' (Free Discharge)
└─**2=Culvert** (Controls 0.00 cfs)

Summary for Pond SC-2: Stormwater Chambers-2

Inflow Area = 1.092 ac, 18.50% Impervious, Inflow Depth = 0.66" for NOAA-010yr event
Inflow = 0.50 cfs @ 12.13 hrs, Volume= 0.060 af
Outflow = 0.07 cfs @ 14.75 hrs, Volume= 0.060 af, Atten= 85%, Lag= 156.8 min
Discarded = 0.07 cfs @ 14.75 hrs, Volume= 0.060 af
Primary = 0.00 cfs @ 1.00 hrs, Volume= 0.000 af
Routed to Reach DP-1 : Lake Quinsigamond

Routing by Stor-Ind method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 368.56' @ 14.75 hrs Surf.Area= 0.022 ac Storage= 0.019 af

Plug-Flow detention time= 122.8 min calculated for 0.060 af (100% of inflow)
Center-of-Mass det. time= 122.7 min (1,039.5 - 916.7)

Volume	Invert	Avail.Storage	Storage Description
#1A	367.00'	0.024 af	**22.75'W x 41.55'L x 5.50'H Field A** 0.119 af Overall - 0.040 af Embedded = 0.079 af x 30.0% Voids
#2A	367.75'	0.040 af	**ADS_StormTech MC-3500 d +Cap** x 15 Inside #1 Effective Size= 70.4"W x 45.0"H => 15.33 sf x 7.17'L = 110.0 cf Overall Size= 77.0"W x 45.0"H x 7.50'L with 0.33' Overlap 15 Chambers in 3 Rows Cap Storage= 14.9 cf x 2 x 3 rows = 89.4 cf
		0.064 af	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Discarded	367.00'	**2.410 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 362.83'
#2	Primary	370.50'	**12.0" Round Culvert** L= 20.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 370.50' / 369.90' S= 0.0300 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Discarded OutFlow Max=0.07 cfs @ 14.75 hrs HW=368.56' (Free Discharge)
└─**1=Exfiltration** (Controls 0.07 cfs)

Primary OutFlow Max=0.00 cfs @ 1.00 hrs HW=367.00' (Free Discharge)
└─**2=Culvert** (Controls 0.00 cfs)

Time span=1.00-36.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment PDA-1A: Plantation Street Runoff Area=0.150 ac 32.67% Impervious Runoff Depth=1.76"
Tc=6.0 min CN=58 Runoff=0.28 cfs 0.022 af

Subcatchment PDA-1B: Parking Lot Runoff Area=0.769 ac 59.69% Impervious Runoff Depth=3.10"
Tc=6.0 min CN=73 Runoff=2.74 cfs 0.198 af

Subcatchment PDA-1C: Park Area Runoff Area=1.092 ac 18.50% Impervious Runoff Depth=1.15"
Tc=6.0 min CN=50 Runoff=1.15 cfs 0.104 af

Subcatchment PDA-1D: Lake Avenue North Runoff Area=3.708 ac 10.60% Impervious Runoff Depth=0.56"
Tc=6.0 min CN=41 Runoff=0.96 cfs 0.173 af

Reach DP-1: Lake Quinsigamond Inflow=1.13 cfs 0.210 af
Outflow=1.13 cfs 0.210 af

Pond SC-1: Stormwater Chambers-1 Peak Elev=380.63' Storage=0.076 af Inflow=2.74 cfs 0.198 af
Discarded=0.25 cfs 0.184 af Primary=0.27 cfs 0.015 af Outflow=0.52 cfs 0.198 af

Pond SC-2: Stormwater Chambers-2 Peak Elev=370.31' Storage=0.045 af Inflow=1.15 cfs 0.104 af
Discarded=0.09 cfs 0.104 af Primary=0.00 cfs 0.000 af Outflow=0.09 cfs 0.104 af

Total Runoff Area = 5.719 ac Runoff Volume = 0.498 af Average Runoff Depth = 1.04"
80.71% Pervious = 4.616 ac 19.29% Impervious = 1.103 ac

Summary for Subcatchment PDA-1A: Plantation Street

Runoff = 0.28 cfs @ 12.10 hrs, Volume= 0.022 af, Depth= 1.76"
Routed to Reach DP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-025yr Rainfall=6.01"

	Area (ac)	CN	Description
	0.101	39	>75% Grass cover, Good, HSG A
*	0.048	98	Existing Impervious, HSG A
*	0.001	98	Proposed Impervious, HSG A
	0.150	58	Weighted Average
	0.101		67.33% Pervious Area
	0.049		32.67% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Subcatchment PDA-1B: Parking Lot

Runoff = 2.74 cfs @ 12.09 hrs, Volume= 0.198 af, Depth= 3.10"
Routed to Pond SC-1 : Stormwater Chambers-1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-025yr Rainfall=6.01"

	Area (ac)	CN	Description
	0.075	30	Woods, Good, HSG A
	0.158	39	>75% Grass cover, Good, HSG A
*	0.077	39	Turf, HSG A
*	0.027	98	Permeable Pavement, HSG A
*	0.002	98	Proposed Impervious, HSG A
*	0.032	98	Existing Impervious, HSG A
*	0.398	98	Paved Parking, HSG A
	0.769	73	Weighted Average
	0.310		40.31% Pervious Area
	0.459		59.69% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc. Min**

Summary for Subcatchment PDA-1C: Park Area

Runoff = 1.15 cfs @ 12.11 hrs, Volume= 0.104 af, Depth= 1.15"
Routed to Pond SC-2 : Stormwater Chambers-2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-025yr Rainfall=6.01"

	Area (ac)	CN	Description
	0.050	30	Woods, Good, HSG A
	0.625	39	>75% Grass cover, Good, HSG A
*	0.215	39	Playground Area, HSG A
*	0.166	98	Permeable Pavement, HSG A
*	0.036	98	Proposed Impervious, HSG A
	1.092	50	Weighted Average
	0.890		81.50% Pervious Area
	0.202		18.50% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc. Min**

Summary for Subcatchment PDA-1D: Lake Avenue North

Runoff = 0.96 cfs @ 12.29 hrs, Volume= 0.173 af, Depth= 0.56"
Routed to Reach DP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-025yr Rainfall=6.01"

	Area (ac)	CN	Description
	2.344	30	Woods, Good, HSG A
	0.883	39	>75% Grass cover, Good, HSG A
*	0.088	98	Permeable Pavement, HSG A
*	0.088	96	Existing Gravel surface, HSG A
*	0.022	98	Proposed Impervious, HSG A
*	0.004	98	Existing Impervious, HSG A
	0.279	98	Water Surface, HSG A
	3.708	41	Weighted Average
	3.315		89.40% Pervious Area
	0.393		10.60% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Reach DP-1: Lake Quinsigamond

Inflow Area = 5.719 ac, 19.29% Impervious, Inflow Depth = 0.44" for NOAA-025yr event
Inflow = 1.13 cfs @ 12.15 hrs, Volume= 0.210 af
Outflow = 1.13 cfs @ 12.15 hrs, Volume= 0.210 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs

Summary for Pond SC-1: Stormwater Chambers-1

Inflow Area = 0.769 ac, 59.69% Impervious, Inflow Depth = 3.10" for NOAA-025yr event
Inflow = 2.74 cfs @ 12.09 hrs, Volume= 0.198 af
Outflow = 0.52 cfs @ 12.56 hrs, Volume= 0.198 af, Atten= 81%, Lag= 28.3 min
Discarded = 0.25 cfs @ 12.56 hrs, Volume= 0.184 af
Primary = 0.27 cfs @ 12.56 hrs, Volume= 0.015 af
Routed to Reach DP-1 : Lake Quinsigamond

Routing by Stor-Ind method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 380.63' @ 12.56 hrs Surf.Area= 0.048 ac Storage= 0.076 af

Plug-Flow detention time= 124.5 min calculated for 0.198 af (100% of inflow)
Center-of-Mass det. time= 124.3 min (955.4 - 831.1)

Volume	Invert	Avail.Storage	Storage Description
#1A	378.33'	0.044 af	**34.75'W x 60.58'L x 3.50'H Field A** 0.169 af Overall - 0.059 af Embedded = 0.110 af x 40.0% Voids
#2A	378.83'	0.059 af	**ADS_StormTech SC-740 +Cap** x 56 Inside #1 Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap 56 Chambers in 7 Rows
		0.103 af	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Discarded	378.33'	**2.410 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 376.33'
#2	Primary	380.33'	**12.0" Round Culvert** L= 8.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 380.33' / 380.25' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Discarded OutFlow Max=0.25 cfs @ 12.56 hrs HW=380.63' (Free Discharge)
└—**1=Exfiltration** (Controls 0.25 cfs)

Primary OutFlow Max=0.27 cfs @ 12.56 hrs HW=380.63' (Free Discharge)
└—**2=Culvert** (Barrel Controls 0.27 cfs @ 2.01 fps)

Summary for Pond SC-2: Stormwater Chambers-2

Inflow Area = 1.092 ac, 18.50% Impervious, Inflow Depth = 1.15" for NOAA-025yr event
Inflow = 1.15 cfs @ 12.11 hrs, Volume= 0.104 af
Outflow = 0.09 cfs @ 15.44 hrs, Volume= 0.104 af, Atten= 92%, Lag= 199.8 min
Discarded = 0.09 cfs @ 15.44 hrs, Volume= 0.104 af
Primary = 0.00 cfs @ 1.00 hrs, Volume= 0.000 af
Routed to Reach DP-1 : Lake Quinsigamond

Routing by Stor-Ind method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 370.31' @ 15.44 hrs Surf.Area= 0.022 ac Storage= 0.045 af

Plug-Flow detention time= 257.9 min calculated for 0.104 af (100% of inflow)
Center-of-Mass det. time= 257.8 min (1,152.1 - 894.3)

Volume	Invert	Avail.Storage	Storage Description
#1A	367.00'	0.024 af	**22.75'W x 41.55'L x 5.50'H Field A** 0.119 af Overall - 0.040 af Embedded = 0.079 af x 30.0% Voids
#2A	367.75'	0.040 af	**ADS_StormTech MC-3500 d +Cap** x 15 Inside #1 Effective Size= 70.4"W x 45.0"H => 15.33 sf x 7.17'L = 110.0 cf Overall Size= 77.0"W x 45.0"H x 7.50'L with 0.33' Overlap 15 Chambers in 3 Rows Cap Storage= 14.9 cf x 2 x 3 rows = 89.4 cf
		0.064 af	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Discarded	367.00'	**2.410 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 362.83'
#2	Primary	370.50'	**12.0" Round Culvert** L= 20.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 370.50' / 369.90' S= 0.0300 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Discarded OutFlow Max=0.09 cfs @ 15.44 hrs HW=370.31' (Free Discharge)
└─**1=Exfiltration** (Controls 0.09 cfs)

Primary OutFlow Max=0.00 cfs @ 1.00 hrs HW=367.00' (Free Discharge)
└─**2=Culvert** (Controls 0.00 cfs)

Time span=1.00-36.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment PDA-1A: Plantation Street Runoff Area=0.150 ac 32.67% Impervious Runoff Depth=2.88"
Tc=6.0 min CN=58 Runoff=0.48 cfs 0.036 af

Subcatchment PDA-1B: Parking Lot Runoff Area=0.769 ac 59.69% Impervious Runoff Depth=4.53"
Tc=6.0 min CN=73 Runoff=4.00 cfs 0.290 af

Subcatchment PDA-1C: Park Area Runoff Area=1.092 ac 18.50% Impervious Runoff Depth=2.06"
Tc=6.0 min CN=50 Runoff=2.35 cfs 0.187 af

Subcatchment PDA-1D: Lake Avenue North Runoff Area=3.708 ac 10.60% Impervious Runoff Depth=1.20"
Tc=6.0 min CN=41 Runoff=3.58 cfs 0.371 af

Reach DP-1: Lake Quinsigamond Inflow=4.73 cfs 0.538 af
Outflow=4.73 cfs 0.538 af

Pond SC-1: Stormwater Chambers-1 Peak Elev=381.14' Storage=0.090 af Inflow=4.00 cfs 0.290 af
Discarded=0.28 cfs 0.219 af Primary=1.47 cfs 0.071 af Outflow=1.76 cfs 0.290 af

Pond SC-2: Stormwater Chambers-2 Peak Elev=371.07' Storage=0.054 af Inflow=2.35 cfs 0.187 af
Discarded=0.10 cfs 0.128 af Primary=0.94 cfs 0.059 af Outflow=1.04 cfs 0.187 af

Total Runoff Area = 5.719 ac Runoff Volume = 0.885 af Average Runoff Depth = 1.86"
80.71% Pervious = 4.616 ac 19.29% Impervious = 1.103 ac

Summary for Subcatchment PDA-1A: Plantation Street

Runoff = 0.48 cfs @ 12.10 hrs, Volume= 0.036 af, Depth= 2.88"
Routed to Reach DP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-100yr Rainfall=7.68"

	Area (ac)	CN	Description
	0.101	39	>75% Grass cover, Good, HSG A
*	0.048	98	Existing Impervious, HSG A
*	0.001	98	Proposed Impervious, HSG A
	0.150	58	Weighted Average
	0.101		67.33% Pervious Area
	0.049		32.67% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Subcatchment PDA-1B: Parking Lot

Runoff = 4.00 cfs @ 12.09 hrs, Volume= 0.290 af, Depth= 4.53"
Routed to Pond SC-1 : Stormwater Chambers-1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-100yr Rainfall=7.68"

	Area (ac)	CN	Description
	0.075	30	Woods, Good, HSG A
	0.158	39	>75% Grass cover, Good, HSG A
*	0.077	39	Turf, HSG A
*	0.027	98	Permeable Pavement, HSG A
*	0.002	98	Proposed Impervious, HSG A
*	0.032	98	Existing Impervious, HSG A
*	0.398	98	Paved Parking, HSG A
	0.769	73	Weighted Average
	0.310		40.31% Pervious Area
	0.459		59.69% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc. Min**

Summary for Subcatchment PDA-1C: Park Area

Runoff = 2.35 cfs @ 12.10 hrs, Volume= 0.187 af, Depth= 2.06"
Routed to Pond SC-2 : Stormwater Chambers-2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-100yr Rainfall=7.68"

	Area (ac)	CN	Description
	0.050	30	Woods, Good, HSG A
	0.625	39	>75% Grass cover, Good, HSG A
*	0.215	39	Playground Area, HSG A
*	0.166	98	Permeable Pavement, HSG A
*	0.036	98	Proposed Impervious, HSG A
	1.092	50	Weighted Average
	0.890		81.50% Pervious Area
	0.202		18.50% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc. Min**

Summary for Subcatchment PDA-1D: Lake Avenue North

Runoff = 3.58 cfs @ 12.12 hrs, Volume= 0.371 af, Depth= 1.20"
Routed to Reach DP-1 : Lake Quinsigamond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr NOAA-100yr Rainfall=7.68"

	Area (ac)	CN	Description
	2.344	30	Woods, Good, HSG A
	0.883	39	>75% Grass cover, Good, HSG A
*	0.088	98	Permeable Pavement, HSG A
*	0.088	96	Existing Gravel surface, HSG A
*	0.022	98	Proposed Impervious, HSG A
*	0.004	98	Existing Impervious, HSG A
	0.279	98	Water Surface, HSG A
	3.708	41	Weighted Average
	3.315		89.40% Pervious Area
	0.393		10.60% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Tc Min.**

Summary for Reach DP-1: Lake Quinsigamond

Inflow Area = 5.719 ac, 19.29% Impervious, Inflow Depth = 1.13" for NOAA-100yr event
Inflow = 4.73 cfs @ 12.35 hrs, Volume= 0.538 af
Outflow = 4.73 cfs @ 12.35 hrs, Volume= 0.538 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs

Summary for Pond SC-1: Stormwater Chambers-1

Inflow Area = 0.769 ac, 59.69% Impervious, Inflow Depth = 4.53" for NOAA-100yr event
Inflow = 4.00 cfs @ 12.09 hrs, Volume= 0.290 af
Outflow = 1.76 cfs @ 12.31 hrs, Volume= 0.290 af, Atten= 56%, Lag= 13.1 min
Discarded = 0.28 cfs @ 12.31 hrs, Volume= 0.219 af
Primary = 1.47 cfs @ 12.31 hrs, Volume= 0.071 af
Routed to Reach DP-1 : Lake Quinsigamond

Routing by Stor-Ind method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 381.14' @ 12.31 hrs Surf.Area= 0.048 ac Storage= 0.090 af

Plug-Flow detention time= 106.8 min calculated for 0.290 af (100% of inflow)
Center-of-Mass det. time= 106.6 min (926.8 - 820.2)

Volume	Invert	Avail.Storage	Storage Description
#1A	378.33'	0.044 af	**34.75'W x 60.58'L x 3.50'H Field A** 0.169 af Overall - 0.059 af Embedded = 0.110 af x 40.0% Voids
#2A	378.83'	0.059 af	**ADS_StormTech SC-740 +Cap** x 56 Inside #1 Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap 56 Chambers in 7 Rows
		0.103 af	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Discarded	378.33'	**2.410 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 376.33'
#2	Primary	380.33'	**12.0" Round Culvert** L= 8.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 380.33' / 380.25' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Discarded OutFlow Max=0.28 cfs @ 12.31 hrs HW=381.14' (Free Discharge)
└─**1=Exfiltration** (Controls 0.28 cfs)

Primary OutFlow Max=1.46 cfs @ 12.31 hrs HW=381.14' (Free Discharge)
└─**2=Culvert** (Barrel Controls 1.46 cfs @ 2.93 fps)

Summary for Pond SC-2: Stormwater Chambers-2

Inflow Area = 1.092 ac, 18.50% Impervious, Inflow Depth = 2.06" for NOAA-100yr event
Inflow = 2.35 cfs @ 12.10 hrs, Volume= 0.187 af
Outflow = 1.04 cfs @ 12.41 hrs, Volume= 0.187 af, Atten= 56%, Lag= 18.1 min
Discarded = 0.10 cfs @ 12.41 hrs, Volume= 0.128 af
Primary = 0.94 cfs @ 12.41 hrs, Volume= 0.059 af
Routed to Reach DP-1 : Lake Quinsigamond

Routing by Stor-Ind method, Time Span= 1.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 371.07' @ 12.41 hrs Surf.Area= 0.022 ac Storage= 0.054 af

Plug-Flow detention time= 198.4 min calculated for 0.187 af (100% of inflow)
Center-of-Mass det. time= 198.6 min (1,072.2 - 873.6)

Volume	Invert	Avail.Storage	Storage Description
#1A	367.00'	0.024 af	**22.75'W x 41.55'L x 5.50'H Field A** 0.119 af Overall - 0.040 af Embedded = 0.079 af x 30.0% Voids
#2A	367.75'	0.040 af	**ADS_StormTech MC-3500 d +Cap** x 15 Inside #1 Effective Size= 70.4"W x 45.0"H => 15.33 sf x 7.17'L = 110.0 cf Overall Size= 77.0"W x 45.0"H x 7.50'L with 0.33' Overlap 15 Chambers in 3 Rows Cap Storage= 14.9 cf x 2 x 3 rows = 89.4 cf
		0.064 af	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Discarded	367.00'	**2.410 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 362.83'
#2	Primary	370.50'	**12.0" Round Culvert** L= 20.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 370.50' / 369.90' S= 0.0300 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Discarded OutFlow Max=0.10 cfs @ 12.41 hrs HW=371.07' (Free Discharge)
└**1=Exfiltration** (Controls 0.10 cfs)

Primary OutFlow Max=0.93 cfs @ 12.41 hrs HW=371.07' (Free Discharge)
└**2=Culvert** (Inlet Controls 0.93 cfs @ 2.02 fps)

Attachment 4
Hydraulic Calculations

HYDRAULIC CALCULATIONS

OBJECTIVE

To size pipes to adequately convey flows from the proposed project and to meet the design standards of the Massachusetts DEP Stormwater Handbook for inlet capacity, pipe flow, and scour.

CONCLUSION

- The proposed pipes will adequately convey the 25-year storm event runoff rates.
- The proposed stormwater management design has been reviewed for compliance with the stormwater management standards described in the Massachusetts DEP Stormwater Management Handbook.

CALCULATION METHODS

- The pipes are designed using the Rational Formula, based on a 25-year storm event for the City of Worcester (see attached IDF curve).

ASSUMPTIONS

- Runoff coefficient C=0.3 for pervious areas and C=0.9 for impervious areas.
- Manning's n=0.012 for HDPE pipe.
- The times of concentration (T_C) for contributing subcatchments are approximately 6 minutes for flows to CB-1, CB-2, WQI, AD-1, and AD-2.
- The minimum full-flow (scour) velocity is 2 feet per second.
- The maximum full-flow (scour) velocity is 10 feet per second.

SOURCES OF DATA/ EQUATIONS

1. Rational Method (Q=CiA) was used to calculate peak runoff rates tributary to CB-1, CB-2, WQI, AD-1, and AD-2.
2. Manning's Equation was used to determine pipe capacities.
3. 25-year storm intensity obtained from the Intensity/Duration rainfall curve for Worcester, MA in S.C.S Technical Report No. 40.
4. Massachusetts DEP Stormwater Management Handbook, February 2008.

REV	CALC. BY	DATE	CHECKED BY	DATE	APPROVED BY	DATE
0	NBB	01/03/2022	DMG	01/03/2022	DMG	01/04/2022

NBB/322801CS003A

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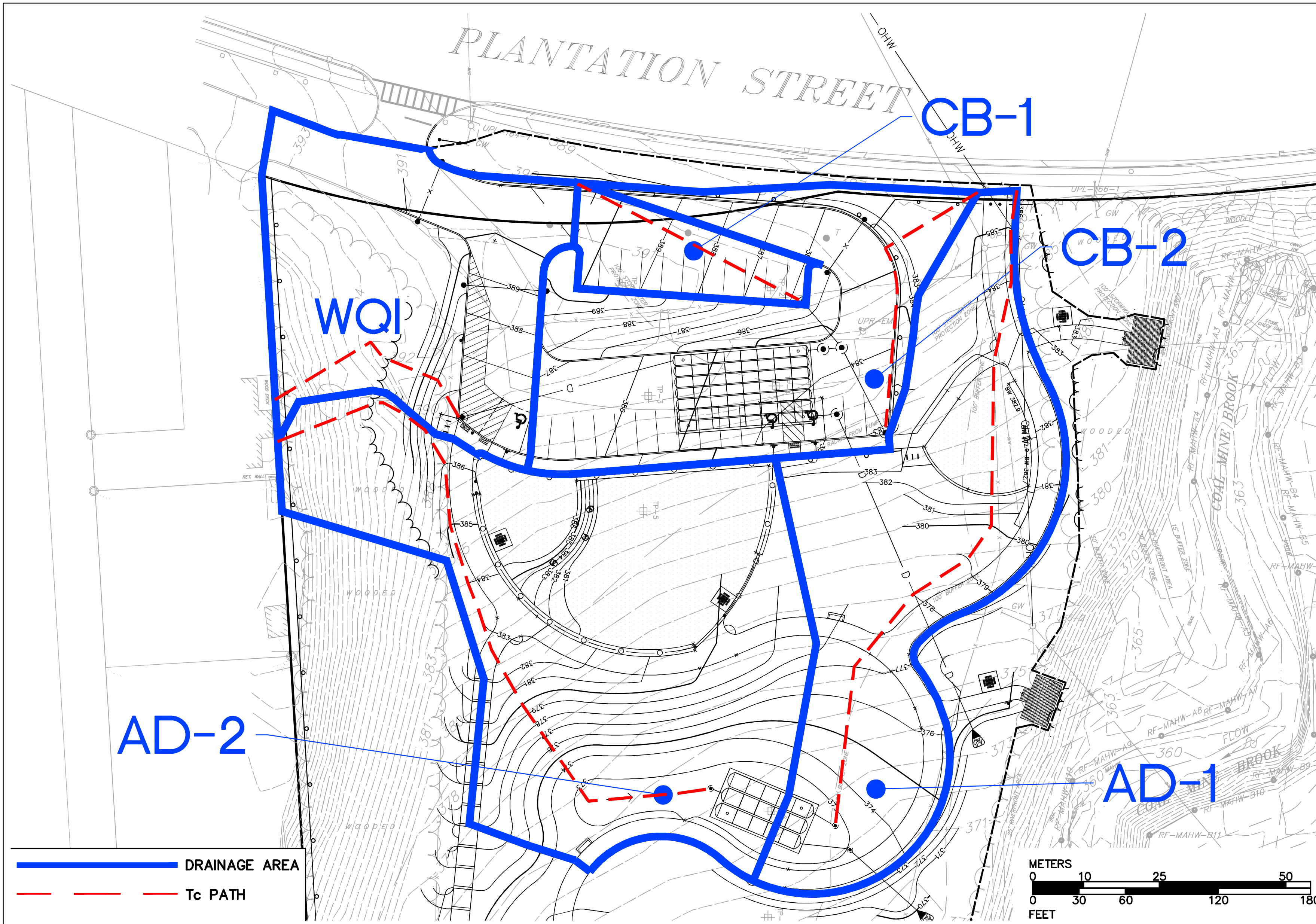

Proposed Hydraulic Areas Map
Figure Number 003
Scale: 1" = 60'
Date: 01/03/2022
Plan No. 322801P004A-003
B+T Project No. 3228.01

Coal Mine Brook
616 Plantation Street
Worcester, Massachusetts

City of Worcester
50 Skyline Drive
Worcester, Massachusetts

North Arrow
NORTH

BEALS AND THOMAS, INC.

DA- CB-1

	AREA	C
PAVED	0.074	0.9
GRASSED	0.001	0.3

Tc=	6	MIN
TOTAL AREA=	0.075	ACRES
WEIGHTED C=	0.89	

DA- CB-2

	AREA	C
PAVED	0.214	0.9
GRASSED	0.154	0.3

Tc=	6	MIN
TOTAL AREA=	0.368	ACRES
WEIGHTED C=	0.65	

DA- WQI

	AREA	C
PAVED	0.144	0.9
GRASSED	0.183	0.3

Tc=	6	MIN
TOTAL AREA=	0.327	ACRES
WEIGHTED C=	0.56	

DA- AD-1

	AREA	C
PAVED	0.008	0.9
GRASSED	0.446	0.3

Tc=	6	MIN
TOTAL AREA=	0.454	ACRES
WEIGHTED C=	0.31	

DA- AD-2

	AREA	C
PAVED	0.028	0.9
GRASSED	0.610	0.3

Tc=	6	MIN
TOTAL AREA=	0.638	ACRES
WEIGHTED C=	0.33	

DA- DMH-1

	AREA	C
PAVED	0.288	0.9
GRASSED	0.155	0.3

Tc=	6	MIN
TOTAL AREA=	0.443	ACRES
WEIGHTED C=	0.69	

JOB NO.	3228.01	COMPUTED BY	NBB	CHECKED BY	DMG
FILE	Coal Mine Brook	DATE	1/3/2022	DATE	1/3/2022

BEALS + THOMAS

Hydraulic Drainage Areas & Corresponding Rational Method Flows

Using the Rational Method:

Q = CIA

Where:

Q = flow (cfs)

C = Runoff Coefficient

I = Rainfall Intensity, 10-year storm (in/hr) (from Worcester, MA IDF curve, see attached

A = Contributing Area (acres)

Assumptions:
- Coefficient of runoff for Gravel Surfaces = 0.9
- Coefficient of runoff for Pervious Surfaces = 0.3

Inlet	Contributing Area (Acres)	Weighted Average Rational Coefficients	Rainfall Intensity for Worcester (in/hr)	Contributing Flow (cfs)
CB-1	0.075	0.89	6.30	0.42
CB-2	0.368	0.65	6.30	1.51
WQI	0.327	0.56	6.30	1.15
AD-1	0.454	0.31	6.30	0.89
AD-2	0.638	0.33	6.30	1.33
DMH-1	0.443	0.69	6.30	1.93

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FILE Coal Mine Brook DATE 1/3/2022 DATE 1/3/2022

BEALS + THOMAS

Hydraulic Pipe Sizing Calculations

Using the Manning Equation to Verify Pipe Capacities Versus Pipe Flows:

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$$

Where:

Q = flow (cfs)
n = Manning's roughness coefficient
A = Cross Sectional Area (sf)
R = Hydraulic Radius (ft)
S = Pipe Slope

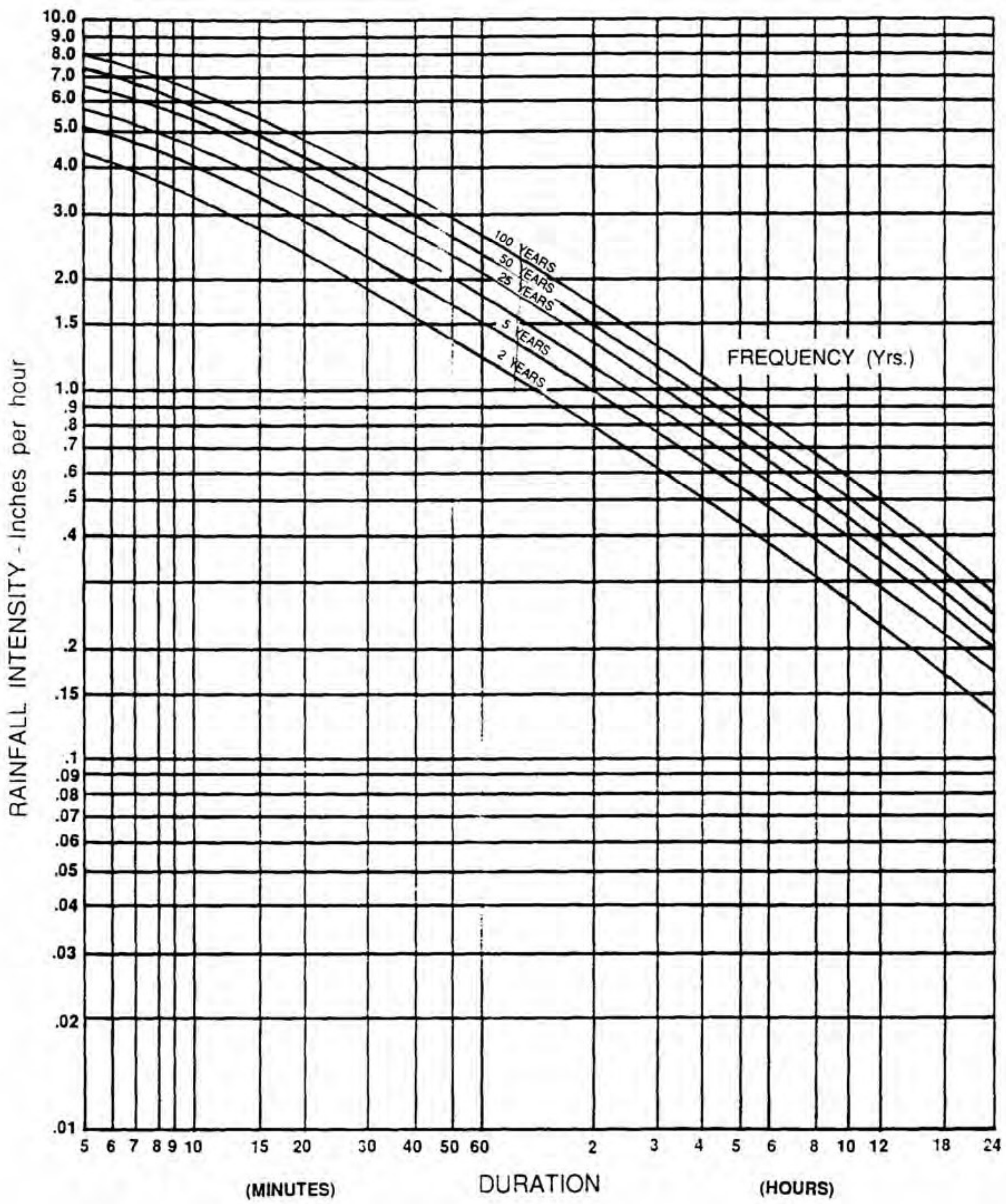
Assumptions: n = 0.013 for HDPE pipe
Pipe velocity shall be between 2.0 ft/sec and 10 ft/sec

Pipe Connection	Contributing Flow-25 Year Storm(cfs)	Proposed Pipe Size and Material	Proposed Pipe Slope (rise/run)	Full-Flow Capacity of Pipe from Manning Equation (cfs)	Adequate	Full Flow Velocity (ft/sec)
CB-1 to DMH-1	0.42	12" HDPE	0.041	7.23	OK	9.2
CB-2 to DMH-2	1.51	12" HDPE	0.010	3.57	OK	4.5
WQI to SC-1	1.15	12" HDPE	0.019	4.92	OK	6.3
AD-1 TO SC-2	0.89	8" HDPE	0.025	1.85	OK	5.4
AD-2 TO SC-2	1.33	8" HDPE	0.025	1.85	OK	5.4
DMH-1 to WQS	1.93	12" HDPE	0.010	3.57	OK	4.5

JOB NO. 3228.01 COMPUTED BY NBB CHECKED BY DMG

FILE Coal Mine Brook DATE 1/3/2022 DATE 1/3/2022

Exhibit 8-14
Intensity – Duration – Frequency Curve for Worcester, MA



Source: TR55 - Urban Hydrology for Small Wetlands, NRCS

BEALS + THOMAS

Catchbasin Grate Sizing

CB #	25-YEAR STORM DESIGN FLOW (CFS)	HEAD (ft) Lebaron LF248-2 (Single grate)	HEAD (ft) Lebaron LV2448-2 (Double grate)	RECOMMENDED GRATE
		A= 1.5625 SF	A= 3.125 SF	
CB-1	0.42	0.003116522	0.0007791	Single
CB-2	1.51	0.04028334	0.0100708	Single

Note: Capacity based on Orifice Flow (ponded condition).

JOB NO. 3228.01
JOB: Coal Mine Brook

COMPUTED BY: NBB
DATE: 1/3/2022

CHECKED BY: DMG
DATE: 1/3/2022

Attachment 5
Groundwater Recharge, TSS Removal, Drawdown, Water Quality Volume, Proprietary Water Quality Inlet Sizing, Rip Rap Apron Sizing, and Groundwater Mounding Calculations

B E A L S + T H O M A S

Standard 3: Groundwater Recharge

Groundwater Recharge Volume Required:

Rv = F x Impervious Area, where:

Rv = Required Recharge Volume [Ac-ft]

F = Target Depth Factor associated with each Hydrologic Soil Group (HSG) [in]

Impervious Area = Total Pavement and Rooftop Area under Post-development Conditions [Ac]

			Impervious Area [Acres]	Required Recharge Volume [Ac-ft]	
HSG "A", use F =	0.6	in	0.318	0.016	*excludes permeable pavement
HSG "B", use F =	0.35	in	0.000	0.000	
HSG "C", use F =	0.25	in	0.000	0.000	
HSG "D", use F =	0.1	in	0.000	0.000	
Total Required Recharge Volume (Rv) =				**0.016**	**Ac-ft**

Capture Area Adjustment: (Ref: DEP Handbook V.3 Ch.1 P.27-28)

Total Site Impervious Area (Total)=	0.318	Acres
Impervious Area Draining to Infiltrative BMPs (infil) =	0.436	Acres (PDA-1B and PDA-1C Impervious Area)
Percent Imp. Area Draining to Infiltrative BMPs =	137.1%	
Capture Area Adjustment Factor = (Total)/(Infil) = Ca =	0.73	
Adjusted Required Recharge Volume = Ca x Rv	**0.012**	**Ac-ft**

Groundwater Recharge Volume Provided :

BMP	Provided Recharge Volume [Ac-ft]	
Stormwater Chambers-1 =	0.066	
Stormwater Chambers-2 =	0.048	
Total Provided Recharge Volume =	**0.114**	**Ac-ft**

PROVIDED GROUNDWATER RECHARGE VOLUME IS GREATER THAN OR EQUAL TO THE REQUIRED RECHARGE VOLUME, THEREFORE PROPOSED STORMWATER MANAGEMENT DESIGN IS IN COMPLIANCE WITH STANDARD 3.

JOB NO.	3228.01	COMPUTED BY:	NBB	CHECKED BY:	DMG
JOB:	Coal Mine Brook	DATE:	1/3/2022	DATE:	1/3/2022

INSTRUCTIONS: *Non-automated: Mar. 4, 2008*

1. Sheet is nonautomated. Print sheet and complete using hand calculations. Column A and B: See MassDEP Structural BMP Table
2. The calculations must be completed using the Column Headings specified in Chart and Not the Excel Column Headings
3. To complete Chart Column D, multiple Column B value within Row x Column C value within Row
4. To complete Chart Column E value, subtract Column D value within Row from Column C within Row
5. Total TSS Removal = Sum All Values in Column D

Location: Stormwater Chambers-1

TSS Removal Calculation

Pre-Treatment				
A BMP[1]	B TSS Removal Rate[1]	C Starting TSS Load*	D Amount Removed (B*C)	E Remaining Load (C-D)
Deep Sump and Hooded Catch Basin	**0.25**	**1.00**	**0.25**	**0.75**
Proprietary Stormwater Treatment Unit	**0.80**	**0.75**	**0.60**	**0.15**

Pre-Treatment TSS Removal = 85%

Project: **Coal Mine Brook**
Prepared By: **NBB**
Date: **1/3/2022**

*Equals remaining load from previous BMP (E) which enters the BMP

INSTRUCTIONS: *Non-automated: Mar. 4, 2008*

1. Sheet is nonautomated. Print sheet and complete using hand calculations. Column A and B: See MassDEP Structural BMP Table
2. The calculations must be completed using the Column Headings specified in Chart and Not the Excel Column Headings
3. To complete Chart Column D, multiple Column B value within Row x Column C value within Row
4. To complete Chart Column E value, subtract Column D value within Row from Column C within Row
5. Total TSS Removal = Sum All Values in Column D

Location: Stormwater Chambers-1

TSS Removal Calculation

Treatment				
A BMP[1]	B TSS Removal Rate[1]	C Starting TSS Load*	D Amount Removed (B*C)	E Remaining Load (C-D)
Deep Sump and Hooded Catch Basin	**0.25**	**1.00**	**0.25**	**0.75**
Proprietary Stormwater Treatment Unit	**0.80**	**0.75**	**0.60**	**0.15**
Stormwater Chambers	**0.80**	**0.15**	**0.12**	**0.03**

Total TSS Removal = 97%

Project: **Coal Mine Brook**

Prepared By: **NBB**

Date: **1/3/2022**

*Equals remaining load from previous BMP (E) which enters the BMP

BEALS + THOMAS

Standard 3: Drawdown

$$\textbf{Drawdown Time} = \frac{\textbf{Rv}}{\textbf{(K) (Bottom Area)}}$$

where:

Rv = Storage Volume Below Outlet [Ac-ft]
K= Infiltration Rate [in/hr]
Bottom Area= Bottom Area of Recharge System [Ac]

Stormwater Chambers-1

Rv =	0.066	Ac-ft	
K =	2.410	in/hr	
Bottom Area =	0.048	Acres	
Drawdown Time =	**6.846**	**Hours**	*< 72 Hours, Design is in compliance with the standard.*

Stormwater Chambers-2

Rv =	0.048	Ac-ft	
K =	2.410	in/hr	
Bottom Area =	0.022	Acres	
Drawdown Time =	**10.864**	**Hours**	*< 72 Hours, Design is in compliance with the standard.*

Note:

1. The infiltration BMPs have been designed to fully drain within 72 hours, therefore the proposed stormwater management design is in compliance with Standard 3 .

2. Infiltration Rate based on Volume 3, Chapter 1, Table 2.3.3 *Rawls Rates* from the 2008 MA DEP Stormwater Management Handbook.

JOB NO.	3228.01	COMPUTED BY:	NBB	CHECKED BY:	DMG
JOB:	Coal Mine Brook	DATE:	1/3/2022	DATE:	1/3/2022

Stage-Area-Storage for Pond SC-1: Stormwater Chambers-1

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
378.33	**0.048**	0.000	380.93	0.048	0.084
378.38	0.048	0.001	380.98	0.048	0.086
378.43	0.048	0.002	381.03	0.048	0.087
378.48	0.048	0.003	381.08	0.048	0.088
378.53	0.048	0.004	381.13	0.048	0.089
378.58	0.048	0.005	381.18	0.048	0.090
378.63	0.048	0.006	381.23	0.048	0.091
378.68	0.048	0.007	381.28	0.048	0.092
378.73	0.048	0.008	381.33	0.048	0.093
378.78	0.048	0.009	381.38	0.048	0.094
378.83	0.048	0.010	381.43	0.048	0.095
378.88	0.048	0.012	381.48	0.048	0.096
378.93	0.048	0.014	381.53	0.048	0.097
378.98	0.048	0.016	381.58	0.048	0.098
379.03	0.048	0.018	381.63	0.048	0.099
379.08	0.048	0.020	381.68	0.048	0.100
379.13	0.048	0.022	381.73	0.048	0.101
379.18	0.048	0.023	381.78	0.048	0.102
379.23	0.048	0.025	381.83	0.048	**0.103**
379.28	0.048	0.027			
379.33	0.048	0.029			
379.38	0.048	0.031			
379.43	0.048	0.033			
379.48	0.048	0.035			
379.53	0.048	0.037			
379.58	0.048	0.039			
379.63	0.048	0.041			
379.68	0.048	0.043			
379.73	0.048	0.045			
379.78	0.048	0.046			
379.83	0.048	0.048			
379.88	0.048	0.050			
379.93	0.048	0.052			
379.98	0.048	0.054			
380.03	0.048	0.055			
380.08	0.048	0.057			
380.13	0.048	0.059			
380.18	0.048	0.061			
380.23	0.048	0.062			
380.28	0.048	0.064			
380.33	0.048	0.066			
380.38	0.048	0.068			
380.43	0.048	0.069			
380.48	0.048	0.071			
380.53	0.048	0.072			
380.58	0.048	0.074			
380.63	0.048	0.076			
380.68	0.048	0.077			
380.73	0.048	0.079			
380.78	0.048	0.080			
380.83	0.048	0.082			
380.88	0.048	0.083			

Stage-Area-Storage for Pond SC-2: Stormwater Chambers-2

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
367.00	**0.022**	0.000	367.52	0.022	0.003
367.01	0.022	0.000	367.53	0.022	0.003
367.02	0.022	0.000	367.54	0.022	0.004
367.03	0.022	0.000	367.55	0.022	0.004
367.04	0.022	0.000	367.56	0.022	0.004
367.05	0.022	0.000	367.57	0.022	0.004
367.06	0.022	0.000	367.58	0.022	0.004
367.07	0.022	0.000	367.59	0.022	0.004
367.08	0.022	0.001	367.60	0.022	0.004
367.09	0.022	0.001	367.61	0.022	0.004
367.10	0.022	0.001	367.62	0.022	0.004
367.11	0.022	0.001	367.63	0.022	0.004
367.12	0.022	0.001	367.64	0.022	0.004
367.13	0.022	0.001	367.65	0.022	0.004
367.14	0.022	0.001	367.66	0.022	0.004
367.15	0.022	0.001	367.67	0.022	0.004
367.16	0.022	0.001	367.68	0.022	0.004
367.17	0.022	0.001	367.69	0.022	0.004
367.18	0.022	0.001	367.70	0.022	0.005
367.19	0.022	0.001	367.71	0.022	0.005
367.20	0.022	0.001	367.72	0.022	0.005
367.21	0.022	0.001	367.73	0.022	0.005
367.22	0.022	0.001	367.74	0.022	0.005
367.23	0.022	0.001	367.75	0.022	0.005
367.24	0.022	0.002	367.76	0.022	0.005
367.25	0.022	0.002	367.77	0.022	0.005
367.26	0.022	0.002	367.78	0.022	0.005
367.27	0.022	0.002	367.79	0.022	0.006
367.28	0.022	0.002	367.80	0.022	0.006
367.29	0.022	0.002	367.81	0.022	0.006
367.30	0.022	0.002	367.82	0.022	0.006
367.31	0.022	0.002	367.83	0.022	0.006
367.32	0.022	0.002	367.84	0.022	0.006
367.33	0.022	0.002	367.85	0.022	0.007
367.34	0.022	0.002	367.86	0.022	0.007
367.35	0.022	0.002	367.87	0.022	0.007
367.36	0.022	0.002	367.88	0.022	0.007
367.37	0.022	0.002	367.89	0.022	0.007
367.38	0.022	0.002	367.90	0.022	0.007
367.39	0.022	0.003	367.91	0.022	0.008
367.40	0.022	0.003	367.92	0.022	0.008
367.41	0.022	0.003	367.93	0.022	0.008
367.42	0.022	0.003	367.94	0.022	0.008
367.43	0.022	0.003	367.95	0.022	0.008
367.44	0.022	0.003	367.96	0.022	0.008
367.45	0.022	0.003	367.97	0.022	0.009
367.46	0.022	0.003	367.98	0.022	0.009
367.47	0.022	0.003	367.99	0.022	0.009
367.48	0.022	0.003	368.00	0.022	0.009
367.49	0.022	0.003	368.01	0.022	0.009
367.50	0.022	0.003	368.02	0.022	0.010
367.51	0.022	0.003	368.03	0.022	0.010

Stage-Area-Storage for Pond SC-2: Stormwater Chambers-2 (continued)

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
368.04	0.022	0.010	368.56	0.022	0.019
368.05	0.022	0.010	368.57	0.022	0.019
368.06	0.022	0.010	368.58	0.022	0.019
368.07	0.022	0.010	368.59	0.022	0.019
368.08	0.022	0.011	368.60	0.022	0.019
368.09	0.022	0.011	368.61	0.022	0.019
368.10	0.022	0.011	368.62	0.022	0.020
368.11	0.022	0.011	368.63	0.022	0.020
368.12	0.022	0.011	368.64	0.022	0.020
368.13	0.022	0.011	368.65	0.022	0.020
368.14	0.022	0.012	368.66	0.022	0.020
368.15	0.022	0.012	368.67	0.022	0.020
368.16	0.022	0.012	368.68	0.022	0.021
368.17	0.022	0.012	368.69	0.022	0.021
368.18	0.022	0.012	368.70	0.022	0.021
368.19	0.022	0.012	368.71	0.022	0.021
368.20	0.022	0.013	368.72	0.022	0.021
368.21	0.022	0.013	368.73	0.022	0.021
368.22	0.022	0.013	368.74	0.022	0.022
368.23	0.022	0.013	368.75	0.022	0.022
368.24	0.022	0.013	368.76	0.022	0.022
368.25	0.022	0.013	368.77	0.022	0.022
368.26	0.022	0.014	368.78	0.022	0.022
368.27	0.022	0.014	368.79	0.022	0.022
368.28	0.022	0.014	368.80	0.022	0.022
368.29	0.022	0.014	368.81	0.022	0.023
368.30	0.022	0.014	368.82	0.022	0.023
368.31	0.022	0.014	368.83	0.022	0.023
368.32	0.022	0.015	368.84	0.022	0.023
368.33	0.022	0.015	368.85	0.022	0.023
368.34	0.022	0.015	368.86	0.022	0.023
368.35	0.022	0.015	368.87	0.022	0.024
368.36	0.022	0.015	368.88	0.022	0.024
368.37	0.022	0.015	368.89	0.022	0.024
368.38	0.022	0.016	368.90	0.022	0.024
368.39	0.022	0.016	368.91	0.022	0.024
368.40	0.022	0.016	368.92	0.022	0.024
368.41	0.022	0.016	368.93	0.022	0.025
368.42	0.022	0.016	368.94	0.022	0.025
368.43	0.022	0.016	368.95	0.022	0.025
368.44	0.022	0.017	368.96	0.022	0.025
368.45	0.022	0.017	368.97	0.022	0.025
368.46	0.022	0.017	368.98	0.022	0.025
368.47	0.022	0.017	368.99	0.022	0.026
368.48	0.022	0.017	369.00	0.022	0.026
368.49	0.022	0.017	369.01	0.022	0.026
368.50	0.022	0.018	369.02	0.022	0.026
368.51	0.022	0.018	369.03	0.022	0.026
368.52	0.022	0.018	369.04	0.022	0.026
368.53	0.022	0.018	369.05	0.022	0.027
368.54	0.022	0.018	369.06	0.022	0.027
368.55	0.022	0.018	369.07	0.022	0.027

Stage-Area-Storage for Pond SC-2: Stormwater Chambers-2 (continued)

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
369.08	0.022	0.027	369.60	0.022	0.035
369.09	0.022	0.027	369.61	0.022	0.035
369.10	0.022	0.027	369.62	0.022	0.035
369.11	0.022	0.027	369.63	0.022	0.035
369.12	0.022	0.028	369.64	0.022	0.036
369.13	0.022	0.028	369.65	0.022	0.036
369.14	0.022	0.028	369.66	0.022	0.036
369.15	0.022	0.028	369.67	0.022	0.036
369.16	0.022	0.028	369.68	0.022	0.036
369.17	0.022	0.028	369.69	0.022	0.036
369.18	0.022	0.029	369.70	0.022	0.037
369.19	0.022	0.029	369.71	0.022	0.037
369.20	0.022	0.029	369.72	0.022	0.037
369.21	0.022	0.029	369.73	0.022	0.037
369.22	0.022	0.029	369.74	0.022	0.037
369.23	0.022	0.029	369.75	0.022	0.037
369.24	0.022	0.030	369.76	0.022	0.037
369.25	0.022	0.030	369.77	0.022	0.038
369.26	0.022	0.030	369.78	0.022	0.038
369.27	0.022	0.030	369.79	0.022	0.038
369.28	0.022	0.030	369.80	0.022	0.038
369.29	0.022	0.030	369.81	0.022	0.038
369.30	0.022	0.030	369.82	0.022	0.038
369.31	0.022	0.031	369.83	0.022	0.038
369.32	0.022	0.031	369.84	0.022	0.039
369.33	0.022	0.031	369.85	0.022	0.039
369.34	0.022	0.031	369.86	0.022	0.039
369.35	0.022	0.031	369.87	0.022	0.039
369.36	0.022	0.031	369.88	0.022	0.039
369.37	0.022	0.032	369.89	0.022	0.039
369.38	0.022	0.032	369.90	0.022	0.039
369.39	0.022	0.032	369.91	0.022	0.040
369.40	0.022	0.032	369.92	0.022	0.040
369.41	0.022	0.032	369.93	0.022	0.040
369.42	0.022	0.032	369.94	0.022	0.040
369.43	0.022	0.032	369.95	0.022	0.040
369.44	0.022	0.033	369.96	0.022	0.040
369.45	0.022	0.033	369.97	0.022	0.040
369.46	0.022	0.033	369.98	0.022	0.041
369.47	0.022	0.033	369.99	0.022	0.041
369.48	0.022	0.033	370.00	0.022	0.041
369.49	0.022	0.033	370.01	0.022	0.041
369.50	0.022	0.034	370.02	0.022	0.041
369.51	0.022	0.034	370.03	0.022	0.041
369.52	0.022	0.034	370.04	0.022	0.041
369.53	0.022	0.034	370.05	0.022	0.042
369.54	0.022	0.034	370.06	0.022	0.042
369.55	0.022	0.034	370.07	0.022	0.042
369.56	0.022	0.034	370.08	0.022	0.042
369.57	0.022	0.035	370.09	0.022	0.042
369.58	0.022	0.035	370.10	0.022	0.042
369.59	0.022	0.035	370.11	0.022	0.042

Stage-Area-Storage for Pond SC-2: Stormwater Chambers-2 (continued)

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
370.12	0.022	0.043	370.64	0.022	0.049
370.13	0.022	0.043	370.65	0.022	0.049
370.14	0.022	0.043	370.66	0.022	0.050
370.15	0.022	0.043	370.67	0.022	0.050
370.16	0.022	0.043	370.68	0.022	0.050
370.17	0.022	0.043	370.69	0.022	0.050
370.18	0.022	0.043	370.70	0.022	0.050
370.19	0.022	0.044	370.71	0.022	0.050
370.20	0.022	0.044	370.72	0.022	0.050
370.21	0.022	0.044	370.73	0.022	0.050
370.22	0.022	0.044	370.74	0.022	0.050
370.23	0.022	0.044	370.75	0.022	0.051
370.24	0.022	0.044	370.76	0.022	0.051
370.25	0.022	0.044	370.77	0.022	0.051
370.26	0.022	0.044	370.78	0.022	0.051
370.27	0.022	0.045	370.79	0.022	0.051
370.28	0.022	0.045	370.80	0.022	0.051
370.29	0.022	0.045	370.81	0.022	0.051
370.30	0.022	0.045	370.82	0.022	0.051
370.31	0.022	0.045	370.83	0.022	0.052
370.32	0.022	0.045	370.84	0.022	0.052
370.33	0.022	0.045	370.85	0.022	0.052
370.34	0.022	0.046	370.86	0.022	0.052
370.35	0.022	0.046	370.87	0.022	0.052
370.36	0.022	0.046	370.88	0.022	0.052
370.37	0.022	0.046	370.89	0.022	0.052
370.38	0.022	0.046	370.90	0.022	0.052
370.39	0.022	0.046	370.91	0.022	0.052
370.40	0.022	0.046	370.92	0.022	0.052
370.41	0.022	0.046	370.93	0.022	0.053
370.42	0.022	0.047	370.94	0.022	0.053
370.43	0.022	0.047	370.95	0.022	0.053
370.44	0.022	0.047	370.96	0.022	0.053
370.45	0.022	0.047	370.97	0.022	0.053
370.46	0.022	0.047	370.98	0.022	0.053
370.47	0.022	0.047	370.99	0.022	0.053
370.48	0.022	0.047	371.00	0.022	0.053
370.49	0.022	0.047	371.01	0.022	0.053
370.50	0.022	0.048	371.02	0.022	0.053
370.51	0.022	0.048	371.03	0.022	0.054
370.52	0.022	0.048	371.04	0.022	0.054
370.53	0.022	0.048	371.05	0.022	0.054
370.54	0.022	0.048	371.06	0.022	0.054
370.55	0.022	0.048	371.07	0.022	0.054
370.56	0.022	0.048	371.08	0.022	0.054
370.57	0.022	0.048	371.09	0.022	0.054
370.58	0.022	0.049	371.10	0.022	0.054
370.59	0.022	0.049	371.11	0.022	0.054
370.60	0.022	0.049	371.12	0.022	0.054
370.61	0.022	0.049	371.13	0.022	0.055
370.62	0.022	0.049	371.14	0.022	0.055
370.63	0.022	0.049	371.15	0.022	0.055

Stage-Area-Storage for Pond SC-2: Stormwater Chambers-2 (continued)

Elevation (feet)	Surface (acres)	Storage (acre-feet)	Elevation (feet)	Surface (acres)	Storage (acre-feet)
371.16	0.022	0.055	371.68	0.022	0.058
371.17	0.022	0.055	371.69	0.022	0.058
371.18	0.022	0.055	371.70	0.022	0.059
371.19	0.022	0.055	371.71	0.022	0.059
371.20	0.022	0.055	371.72	0.022	0.059
371.21	0.022	0.055	371.73	0.022	0.059
371.22	0.022	0.055	371.74	0.022	0.059
371.23	0.022	0.055	371.75	0.022	0.059
371.24	0.022	0.055	371.76	0.022	0.059
371.25	0.022	0.055	371.77	0.022	0.059
371.26	0.022	0.056	371.78	0.022	0.059
371.27	0.022	0.056	371.79	0.022	0.059
371.28	0.022	0.056	371.80	0.022	0.059
371.29	0.022	0.056	371.81	0.022	0.059
371.30	0.022	0.056	371.82	0.022	0.059
371.31	0.022	0.056	371.83	0.022	0.059
371.32	0.022	0.056	371.84	0.022	0.059
371.33	0.022	0.056	371.85	0.022	0.060
371.34	0.022	0.056	371.86	0.022	0.060
371.35	0.022	0.056	371.87	0.022	0.060
371.36	0.022	0.056	371.88	0.022	0.060
371.37	0.022	0.056	371.89	0.022	0.060
371.38	0.022	0.056	371.90	0.022	0.060
371.39	0.022	0.056	371.91	0.022	0.060
371.40	0.022	0.057	371.92	0.022	0.060
371.41	0.022	0.057	371.93	0.022	0.060
371.42	0.022	0.057	371.94	0.022	0.060
371.43	0.022	0.057	371.95	0.022	0.060
371.44	0.022	0.057	371.96	0.022	0.060
371.45	0.022	0.057	371.97	0.022	0.060
371.46	0.022	0.057	371.98	0.022	0.060
371.47	0.022	0.057	371.99	0.022	0.060
371.48	0.022	0.057	372.00	0.022	0.060
371.49	0.022	0.057	372.01	0.022	0.061
371.50	0.022	0.057	372.02	0.022	0.061
371.51	0.022	0.057	372.03	0.022	0.061
371.52	0.022	0.057	372.04	0.022	0.061
371.53	0.022	0.057	372.05	0.022	0.061
371.54	0.022	0.057	372.06	0.022	0.061
371.55	0.022	0.058	372.07	0.022	0.061
371.56	0.022	0.058	372.08	0.022	0.061
371.57	0.022	0.058	372.09	0.022	0.061
371.58	0.022	0.058	372.10	0.022	0.061
371.59	0.022	0.058	372.11	0.022	0.061
371.60	0.022	0.058	372.12	0.022	0.061
371.61	0.022	0.058	372.13	0.022	0.061
371.62	0.022	0.058	372.14	0.022	0.061
371.63	0.022	0.058	372.15	0.022	0.061
371.64	0.022	0.058	372.16	0.022	0.062
371.65	0.022	0.058	372.17	0.022	0.062
371.66	0.022	0.058	372.18	0.022	0.062
371.67	0.022	0.058	372.19	0.022	0.062

Stage-Area-Storage for Pond SC-2: Stormwater Chambers-2 (continued)

Elevation (feet)	Surface (acres)	Storage (acre-feet)
372.20	0.022	0.062
372.21	0.022	0.062
372.22	0.022	0.062
372.23	0.022	0.062
372.24	0.022	0.062
372.25	0.022	0.062
372.26	0.022	0.062
372.27	0.022	0.062
372.28	0.022	0.062
372.29	0.022	0.062
372.30	0.022	0.062
372.31	0.022	0.063
372.32	0.022	0.063
372.33	0.022	0.063
372.34	0.022	0.063
372.35	0.022	0.063
372.36	0.022	0.063
372.37	0.022	0.063
372.38	0.022	0.063
372.39	0.022	0.063
372.40	0.022	0.063
372.41	0.022	0.063
372.42	0.022	0.063
372.43	0.022	0.063
372.44	0.022	0.063
372.45	0.022	0.063
372.46	0.022	0.063
372.47	0.022	0.064
372.48	0.022	0.064
372.49	0.022	0.064
372.50	0.022	**0.064**

BEALS + THOMAS

Standard 4: Water Quality Volume Summary

$$V_{WQ} = (D_{WQ} / 12 \text{ in/ft}) \times (A_{IMP} \times 43{,}560 \text{ SF/Ac}) \quad \text{where:}$$

V_{WQ} = Required Water Quality Volume [CF]

D_{WQ} = Water Quality Depth : 1-inch for discharges within a Zone II or Interim Wellhead Protection Area, to or near critical areas, runoff from LUHPPL, or exfiltration to soil with infiltration rate 2.4 in/hr or greater; ½-inch for discharges to other areas.

A_{IMP} = Post-development Impervious Area; may exclude roof top areas [Ac]

Required Water Quality Volume:

Drainage Area/ Treatment Train	New A_{IMP} [Ac]	D_{WQ} [in]	V_{WQ} Required [CF]	
PDA-1A	0.000	1	0	
PDA-1B	0.432	1	1,568	
PDA-1C	0.000	1	0	
PDA-1D	0.000	1	0	
Total Required Water Quality Volume:			1,568	Cubic Feet

Provided Water Quality Volume:

Drainage Area/ Treatment Train	BMP	Water Quality Volume Provided [CF]	
PDA-1B	WQS & WQI	1,572	
PDA-1B	Stormwater Chambers-1	2,868	
Total Provided Water Quality Volume:		4,440	Cubic Feet

WATER QUALITY VOLUME PROVIDED IS GREATER THAN OR EQUAL TO THE REQUIRED WATER QUALITY VOLUME, THEREFORE PROPOSED STORMWATER MANAGEMENT DESIGN IS IN COMPLIANCE WITH STANDARD 4.

JOB NO.	3228.01	COMPUTED BY:	NBB	CHECKED BY:	DMG
JOB:	Coal Mine Brook	DATE:	1/3/2022	DATE:	1/3/2022

BEALS + THOMAS

Proprietary Water Quality Inlet Sizing

Step 1: Define Minimum Flow Rate per Water Quality Inlet to Treat Desired Water Quality Volume

Water quality inlets are sized based on flow rate; therefore expressing Water Quality Volume as a flow rate based on the percentage of cumulative average volume captured ensures systems are sized to achieve the desired Water Quality treatment level.

$Q = (q_u)(A)(WQV)$ where:

Q = peak flow rate associated with first 1.0-inch of runoff [CFS]

q_u = The Peak Discharge [CFS/mi^2/in] Massachusetts DEP Standard Method to Convert Required Water Quality Volume to a Discharge Rate for Sizing Flow Based Manufactured Proprietary Stormwater Treatment Practices

A = Contributing Drainage Area, Impervious Surface Only [Ac]

WQV = The Water Quality Treatment Depth [In]

WQI No.	A (Ac)	Tc (Min)	WQV (in)	q_u (csm/in)	Q (cfs)
WQS	0.29	6.0	1.0	774	0.35
WQI	0.14	6.0	1.0	774	0.17
Total	0.43	Acres			

Step 2: Size Water Quality Inlet as recommended by Manufacturer

See attached Sizing Report(s) for recommended model(s).

Step 3: Water Quality Volume Provided by WQI unit(s)

Total Impervious Area Treated by WQI unit(s):	0.43	Acres
	18,861	SF
Treated Water Quality Depth : (accounted for by Average Water Quality Flow Rate)	1.0	inches
Total Water Quality Volume provided by Water Quality Inlets:	**1,572**	**CF**

JOB NO.	3228.01	COMPUTED BY:	NBB	CHECKED BY:	DMG
JOB:	Coal Mine Brook	DATE:	1/3/2022	DATE:	1/3/2022

Stage-Area-Storage for Pond SC-1: Stormwater Chambers-1

Elevation (feet)	Surface (sq-ft)	Storage (cubic-feet)
378.33	**2,105**	0
378.38	2,105	42
378.43	2,105	84
378.48	2,105	126
378.53	2,105	168
378.58	2,105	211
378.63	2,105	253
378.68	2,105	295
378.73	2,105	337
378.78	2,105	379
378.83	2,105	421
378.88	2,105	508
378.93	2,105	594
378.98	2,105	680
379.03	2,105	767
379.08	2,105	853
379.13	2,105	938
379.18	2,105	1,024
379.23	2,105	1,109
379.28	2,105	1,193
379.33	2,105	1,278
379.38	2,105	1,362
379.43	2,105	1,446
379.48	2,105	1,529
379.53	2,105	1,612
379.58	2,105	1,694
379.63	2,105	1,776
379.68	2,105	1,858
379.73	2,105	1,939
379.78	2,105	2,019
379.83	2,105	2,100
379.88	2,105	2,179
379.93	2,105	2,258
379.98	2,105	2,337
380.03	2,105	2,415
380.08	2,105	2,492
380.13	2,105	2,568
380.18	2,105	2,644
380.23	2,105	2,720
380.28	2,105	2,794
380.33	2,105	2,868
380.38	2,105	2,941
380.43	2,105	3,013
380.48	2,105	3,084
380.53	2,105	3,154
380.58	2,105	3,223
380.63	2,105	3,291
380.68	2,105	3,358
380.73	2,105	3,424
380.78	2,105	3,489
380.83	2,105	3,552
380.88	2,105	3,614
380.93	2,105	3,674
380.98	2,105	3,732
381.03	2,105	3,788
381.08	2,105	3,840
381.13	2,105	3,890
381.18	2,105	3,937
381.23	2,105	3,983
381.28	2,105	4,027
381.33	2,105	4,070
381.38	2,105	4,112
381.43	2,105	4,154
381.48	2,105	4,196
381.53	2,105	4,238
381.58	2,105	4,280
381.63	2,105	4,322
381.68	2,105	4,364
381.73	2,105	4,406
381.78	2,105	4,449
381.83	2,105	**4,491**

Project:	**Cole Mine Brook**
Location:	**Worcester, MA**
Prepared For:	**Beals + Thomas**

CONTECH ENGINEERED SOLUTIONS

Purpose: To calculate the water quality flow rate (WQF) over a given site area. In this situation the WQF is derived from the first 1" of runoff from the contributing impervious surface.

Reference: Massachusetts Dept. of Environmental Protection Wetlands Program / United States Department of Agriculture Natural Resources Conservation Service TR-55 Manual

Procedure: Determine unit peak discharge using Figure 1 or 2. Figure 2 is in tabular form so is preferred. Using the tc, read the unit peak discharge (qu) from Figure 1 or Table in Figure 2. qu is expressed in the following units: cfs/mi^2/watershed inches (csm/in).

Compute Q Rate using the following equation:

Q = (qu) (A) (WQV)

where:

Q = flow rate associated with first 1" of runoff
qu = the unit peak discharge, in csm/in.
A = impervious surface drainage area (in square miles)
WQV = water quality volume in watershed inches (1" in this case)

Structure Name	Impv. (acres)	A (miles^2)	t_c (min)	t_c (hr)	WQV (in)	qu (csm/in.)	Q (cfs)
WQS	0.31	0.0004844	6.0	0.100	1.00	774.00	0.37
WQI	0.15	0.0002344	6.0	0.100	1.00	774.00	0.18

The WQf sizing calculation selects the minimum size CDS/Cascade/StormCeptor model capable of operating at the computed WQf peak flowrate prior to bypassing. It assumes free discharge of the WQf through the unit and ignores the routing effect of any upstream storm drain piping. As with all hydrodynamic separators, there will be some impact to the Hydraulic Gradient of the corresponding drainage system, and evaluation of this impact should be considered in the design.

CONTECH ENGINEERED SOLUTIONS

CDS TECHNOLOGIES

CDS ESTIMATED NET ANNUAL SOLIDS LOAD REDUCTION BASED ON THE RATIONAL RAINFALL METHOD

COLE MINE BROOK
WORCESTER, MA

Area	0.31 ac	Unit Site Designation	WQS
Weighted C	0.9	Rainfall Station #	70
t_c	6 min		
CDS Model	1515-3	CDS Treatment Capacity	**1.0 cfs**

Rainfall Intensity[1] (in/hr)	Percent Rainfall Volume[1]	Cumulative Rainfall Volume	Total Flowrate (cfs)	Treated Flowrate (cfs)	Incremental Removal (%)
0.04	15.1%	15.1%	0.01	0.01	14.6
0.08	24.6%	39.7%	0.02	0.02	23.5
0.12	13.7%	53.4%	0.03	0.03	13.0
0.16	9.4%	62.8%	0.04	0.04	8.9
0.20	6.6%	69.5%	0.06	0.06	6.2
0.24	5.2%	74.7%	0.07	0.07	4.9
0.28	4.8%	79.5%	0.08	0.08	4.4
0.32	3.1%	82.6%	0.09	0.09	2.9
0.36	2.7%	85.3%	0.10	0.10	2.4
0.40	2.1%	87.4%	0.11	0.11	1.9
0.48	2.5%	89.9%	0.13	0.13	2.2
0.56	2.0%	91.9%	0.16	0.16	1.7
0.64	1.4%	93.3%	0.18	0.18	1.2
0.72	1.0%	94.3%	0.20	0.20	0.8
0.80	1.1%	95.4%	0.22	0.22	0.9
1.00	1.6%	97.1%	0.28	0.28	1.3
1.20	0.9%	98.0%	0.33	0.33	0.7
1.40	0.6%	98.6%	0.39	0.39	0.4
1.60	0.5%	99.1%	0.45	0.45	0.3
1.80	0.5%	99.6%	0.50	0.50	0.3
0.00	0.0%	99.6%	0.00	0.00	0.0
					92.5

Removal Efficiency Adjustment[2] =	0.0%
Predicted % Annual Rainfall Treated =	99.6%
Predicted Net Annual Load Removal Efficiency =	**92.5%**

1 - Based on 14 years of 15-minute rainfall data from NCDC Station 2107, East Brimfield Lake, Worcester County, M

2 - Reduction due to use of 60-minute data for a site that has a time of concentration less than 30-minutes.

CDS ESTIMATED NET ANNUAL SOLIDS LOAD REDUCTION BASED ON THE RATIONAL RAINFALL METHOD

COLE MINE BROOK
WORCESTER, MA

Area	0.15 ac	Unit Site Designation	WQI
Weighted C	0.9	Rainfall Station #	70
t_c	6 min		
CDS Model	1515-3	CDS Treatment Capacity	1.0 cfs

Rainfall Intensity[1] (in/hr)	Percent Rainfall Volume[1]	Cumulative Rainfall Volume	Total Flowrate (cfs)	Treated Flowrate (cfs)	Incremental Removal (%)
0.04	15.1%	15.1%	0.01	0.01	14.7
0.08	24.6%	39.7%	0.01	0.01	23.7
0.12	13.7%	53.4%	0.02	0.02	13.2
0.16	9.4%	62.8%	0.02	0.02	9.0
0.20	6.6%	69.5%	0.03	0.03	6.3
0.24	5.2%	74.7%	0.03	0.03	5.0
0.28	4.8%	79.5%	0.04	0.04	4.5
0.32	3.1%	82.6%	0.04	0.04	3.0
0.36	2.7%	85.3%	0.05	0.05	2.5
0.40	2.1%	87.4%	0.05	0.05	2.0
0.48	2.5%	89.9%	0.06	0.06	2.3
0.56	2.0%	91.9%	0.08	0.08	1.9
0.64	1.4%	93.3%	0.09	0.09	1.3
0.72	1.0%	94.3%	0.10	0.10	0.9
0.80	1.1%	95.4%	0.11	0.11	1.0
1.00	1.6%	97.1%	0.14	0.14	1.5
1.20	0.9%	98.0%	0.16	0.16	0.8
1.40	0.6%	98.6%	0.19	0.19	0.5
1.60	0.5%	99.1%	0.22	0.22	0.4
1.80	0.5%	99.6%	0.24	0.24	0.4
0.00	0.0%	99.6%	0.00	0.00	0.0
					94.7

Removal Efficiency Adjustment[2] =	0.0%
Predicted % Annual Rainfall Treated =	99.6%
Predicted Net Annual Load Removal Efficiency =	**94.7%**

1 - Based on 14 years of 15-minute rainfall data from NCDC Station 2107, East Brimfield Lake, Worcester County, M

2 - Reduction due to use of 60-minute data for a site that has a time of concentration less than 30-minutes.

BEALS + THOMAS

Riprap Apron Sizing

Median Stone Sizing:

$$D_{50} = 0.2 D_0 \left(\frac{Q}{\sqrt{g} D_0^{2.5}} \right)^{\frac{4}{3}} \left(\frac{D_0}{TW} \right)$$

Where:

D_0 = Maximum Inside Pipe Diameter (ft)

D_{50} = Median Riprap Diameter (ft)

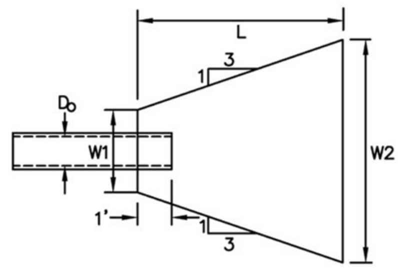
Q = Peak Discharge Rate from Hydraulic Design (cfs)

TW = Tailwater Depth (ft); (Use $0.4D_0$ if TW is unknown, max $1.0D_{o)}$

g = Gravitational Acceleration Constant = 32.2 ft/s^2

Apron Sizing:

D_{50} [In]	Apron Length (L) [ft}	Apron Depth [In]	Apron Width At Beginning (W_1)[ft]	Apron Width At End (W_2) [ft]
5	$4D_0$	$3.5D_{50}$	$3D_0$	$3D_0$ + ⅔L
6	$4D_0$	$3.3D_{50}$	$3D_0$	$3D_0$ + ⅔L
10	$5D_0$	$2.4D_{50}$	$3D_0$	$3D_0$ + ⅔L
14	$6D_0$	$2.2D_{50}$	$3D_0$	$3D_0$ + ⅔L
20	$7D_0$	$2.0D_{50}$	$3D_0$	$3D_0$ + ⅔L
22	$8D_0$	$2.0D_{50}$	$3D_0$	$3D_0$ + ⅔L



FLARED END SECTION	PIPE DIAMETER (D_0) (FEET)	100-YEAR STORM FLOW (Q) (CFS)	TAILWATER (TW) [ft]	MEDIAN STONE DIAMETER (D_{50}) (INCHES)	APRON LENGTH (L) (FEET)	APRON DEPTH [In]	APRON WIDTH AT BEGINING (W_1) [ft]	APRON WIDTH AT END (W_2) [ft]
FE-01	1.0	1.47	0.4	5	4.00	17.5	3.0	5.7
FE-02	1.0	0.94	0.4	5	4.00	17.5	3.0	5.7

Notes

[1] Calculations performed in accordance with Hydraulic Engineering Circular No. 14, Third Edition; Hydraulic Design of Energy Dissipaters for Culverts and Channels, dated July 2006.

[2] Pipe shall extend 1 foot into riprap.

[3] For maximum pipe size of 60".

[4] 100-Year storm flows from Hydrocad used for calculation.

JOB NO. 3228.01 COMPUTED BY: NBB CHECKED BY: DMG

JOB: Coal Mine Brook DATE: 1/3/2022 DATE: 1/3/2022

SWM CHAMBERS-1 GROUNDWATER MOUNTING CALCULATION SUMMARY

OBJECTIVE

To determine the maximum groundwater mounting height beneath the stormwater chambers-1.

CONCLUSION(S)

The mounding analysis indicates that the groundwater elevation would rise approximately 1.140-feet to infiltrate the required volume. Therefore, it can be concluded that the rise in groundwater elevation will not prohibit the stormwater chambers from dewatering within 72 hours.

CALCULATION METHODS

1. Estimated maximum groundwater mounding height calculated using Hantush equation.

ASSUMPTIONS

1. Vertical hydraulic conductivity [R] (unsaturated zone) is equal to the infiltration rate of the proposed stormwater chambers = 2.41 in/hr = 4.82 ft/day.
2. Horizontal hydraulic conductivity [K] (saturated zone) is 200 ft/day based on data provided in USGS Report 86-4053A for mixed sand and gravel.
3. Specific yield [Sy] is 0.26 based on data provided in GSWS Paper 1662-D for Medium Sand
4. Estimated saturated thickness [hi(0)] is 10.00 ft based upon observed seasonal high groundwater and additional field observations during subsurface explorations.
5. ½ the length of stormwater chambers (in x direction) [x] = 30.280 ft
6. ½ the width of stormwater chambers (in y direction) [y] = 17.375 ft
7. The stormwater chambers takes approximately 6.846 hours (t=0.258 days) to dewater.

SOURCES OF DATA/ EQUATIONS

1. Hantush equation spreadsheet published by the USGS.
2. Page 2 of USGS Report 86-4053A, *Yield and Quality of Ground Water from Stratified-Drift Aquifers, Taunton River Basin, Massachusetts: Executive Summary,* 1989.
3. Page D1 of GWSWS Paper 1662-D, *Specific Yield – Compilation of Specific Yields for Various Materials,* 1967.
4. *Massachusetts Stormwater Handbook,* 2008

REV	CALC. BY	DATE	CHECKED BY	DATE	APPROVED BY	DATE
0	NBB	01/03/2022	DMG	01/03/2022	DMG	01/04/2022

NBB/322801CS004A

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32 Court Street
Plymouth, MA 02360

This spreadsheet will calculate the height of a groundwater mound beneath a stormwater infiltration basin. More information can be found in the U.S. Geological Survey Scientific Investigations Report 2010-5102 "Simulation of groundwater mounding beneath hypothetical stormwater infiltration basins".

The user must specify infiltration rate (R), specific yield (Sy), horizontal hydraulic conductivity (Kh), basin dimensions (x, y), duration of infiltration period (t), and the initial thickness of the saturated zone (hi(0), height of the water table if the bottom of the aquifer is the datum). For a square basin the half width equals the half length (x = y). For a rectangular basin, if the user wants the water-table changes perpendicular to the long side, specify x as the short dimension and y as the long dimension. Conversely, if the user wants the values perpendicular to the short side, specify y as the short dimension, x as the long dimension. All distances are from the center of the basin. Users can change the distances from the center of the basin at which water-table aquifer thickness are calculated.
Cells highlighted in yellow are values that can be changed by the user. Cells highlighted in red are output values based on user-specified inputs. The user MUST click the blue "Re-Calculate Now" button each time ANY of the user-specified inputs are changed otherwise necessary iterations to converge on the correct solution will not be done and values shown will be incorrect. Use consistent units for all input values (for example, feet and days)

use consistent units (e.g. feet & days **or** inches & hours)

Input Values

4.8200	*R*	**Recharge (infiltration) rate (feet/day)**
0.260	**Sy**	**Specific yield, Sy (dimensionless, between 0 and 1)**
200.00	**K**	**Horizontal hydraulic conductivity, Kh (feet/day)***
30.280	**x**	**1/2 length of basin (x direction, in feet)**
17.375	**y**	**1/2 width of basin (y direction, in feet)**
0.285	**t**	**duration of infiltration period (days)**
10.000	**hi(0)**	**initial thickness of saturated zone (feet)**
11.140	**h(max)**	**maximum thickness of saturated zone (beneath center of basin at end of infiltration period)**
1.140	**Δh(max)**	**maximum groundwater mounding (beneath center of basin at end of infiltration period)**

Conversion Table

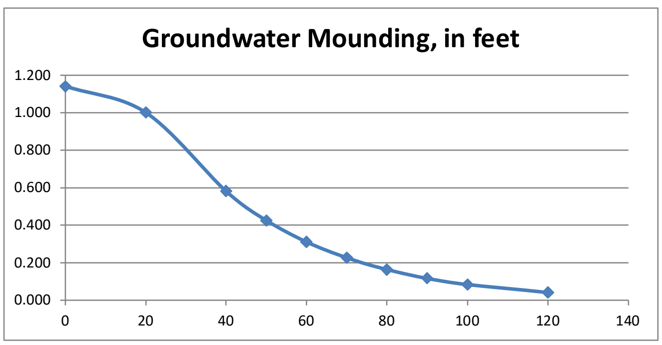
inch/hour	**feet/day**
0.67	1.33
2.00	4.00

hours	**days**
36	1.50

In the report accompanying this spreadsheet (USGS SIR 2010-5102), vertical soil permeability (ft/d) is assumed to be one-tenth horizontal hydraulic conductivity (ft/d).

Ground-water Mounding, in feet	**Distance from center of basin in x direction, in feet**
1.140	0
1.001	20
0.582	40
0.425	50
0.311	60
0.227	70
0.164	80
0.118	90
0.084	100
0.041	120

Re-Calculate Now



Disclaimer

This spreadsheet solving the Hantush (1967) equation for ground-water mounding beneath an infiltration basin is made available to the general public as a convenience for those wishing to replicate values documented in the USGS Scientific Investigations Report 2010-5102 "Groundwater mounding beneath hypothetical stormwater infiltration basins" or to calculate values based on user-specified site conditions. Any changes made to the spreadsheet (other than values identified as user-specified) after transmission from the USGS could have unintended, undesirable consequences. These consequences could include, but may not be limited to: erroneous output, numerical instabilities, and violations of underlying assumptions that are inherent in results presented in the accompanying USGS published report. The USGS assumes no responsibility for the consequences of any changes made to the spreadsheet. If changes are made to the spreadsheet, the user is responsible for documenting the changes and justifying the results and conclusions.

YIELD AND QUALITY OF GROUND WATER FROM STRATIFIED-DRIFT AQUIFERS, TAUNTON RIVER BASIN, MASSACHUSETTS: EXECUTIVE SUMMARY

By Wayne W. Lapham and Julio C. Olimpio

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 86-4053A

Prepared in cooperation with

COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
DIVISION OF WATER RESOURCES

Boston, Massachusetts
1989

PHYSICAL SETTING AND HYDROGEOLOGY OF THE BASIN

The Taunton River basin covers 530 mi^2 (square miles) of Bristol, Norfolk, and Plymouth Counties in southeastern Massachusetts. All or parts of the cities of Attleboro, Brockton, Fall River, New Bedford, and Taunton, and 36 towns are in the basin (fig. 1). The basin is drained by the Matfield, Town, and Taunton Rivers.

Tributary streams include the Canoe, Nemasket, Wading, Threemile, and Winnetuxet Rivers. Surface-water drainage is generally southward toward Mount Hope Bay, a part of Narragansett Bay at Fall River.

Stratified-drift deposits cover about 62 percent of the basin. These deposits are primarily ice-contact, outwash, and lake-bottom sediments, which were deposited in preglacial bedrock valleys and in water-filled depressions in the till and bedrock surface during retreat of the last glacier. The sediments are composed of sand, gravel, cobbles, silt, and clay. The drift ranges in thickness from zero to about 200 ft (feet) in some of the deep preglacial bedrock valleys. The thickest deposits are lake-bottom deposits composed of fine sand interbedded with silt and clay. Stratified-drift deposits are more abundant in the central and southern parts of the basin than in the northern part of the basin. In the northern one-third of the basin, stratified drift fills narrow, north-south trending valleys, which are bordered by till and bedrock uplands.

Yields of wells in the fine-grained stratified-drift deposits are usually no more than a few gallons per minute (gal/min) whereas yields of wells in the coarse-grained stratified drift may exceed 300 gal/min. The coarse-grained parts of the stratified-drift deposits form the major aquifers in the basin. In the northern part of the basin, these aquifers are long, narrow, and thin, and have saturated thicknesses that range from about 20 ft to somewhat more than 100 ft. The widths of the stratified-drift aquifers generally range from 0.1 to 1.5 mi (miles), and their lengths generally range from 1 to 5 mi.

Twenty-six stratified-drift aquifers in the northern half of the basin were studied in detail (fig. 2). These aquifers were selected because current and projected 1990 water-supply deficits are greatest in the northern half of the basin, affecting 14 of 19 municipalities. In contrast, only one of nine municipalities in the southern half of the basin is projected to have a deficit (Richard Thibedeau, Massachusetts Division of Water Resources, written commun.,1984). The 26 aquifers also were selected because the use of ground water as the sole source of supply is greatest in the northern half of the basin. Fifteen of 19 municipalities in the northern half of the basin use ground water as compared to 4 of 9 municipalities in the southern half of the basin.

The 26 stratified-drift aquifers were identified as areas of stratified drift that have a transmissivity equal to or greater than 1,337 ft^2/d (square feet per day), which is equivalent to 10,000 gallons per day per foot. The aquifers underlie or are near major rivers or tributaries. The aquifers are composed mostly of layers of sand and gravel but include some interbedded layers of silt and clay. John R. Williams (U.S. Geological Survey, written commun., 1982) determined that the hydraulic conductivity of fine-to-coarse gravel ranges from about 150 to 500 ft/d (feet per day), mixed sand and gravel averages about 200 ft/d, and fine-to-coarse sand ranges from about 25 to 150 ft/d. The transmissivity of the stratified drift is equal to the product of its hydraulic conductivity and saturated thickness. Therefore, equal transmissivities at different locations in an aquifer may be the result of thin deposits of high-conductivity drift or thick deposits of low-conductivity drift. Transmissivity exceeds 4,000 ft^2/d in small areas in nearly all 26 aquifers. In a few areas, where the stratified drift is thick or has a high hydraulic conductivity, transmissivity exceeds 10,000 ft^2/d.

AQUIFER YIELDS

Estimates from Model Simulations

During severe drought, ground-water discharge from aquifers to streams is reduced or ceases, streamflow is at a minimum, and only small amounts of surface water are stored in wetlands and ponds. Consequently, water pumped from most aquifers in New England during severe drought is derived largely from storage in the aquifers. During normal climatic conditions, water pumped from an aquifer is derived from storage, intercepted ground-water discharge, and induced infiltration of surface water. To account for drought and normal conditions, two sets of aquifer-yield estimates were made for each of the 26 stratified-drift aquifers using simple ground-water flow models. "Short-term" aquifer yields during drought conditions were determined by considering only water from storage and are expressed as single values for several selected pumping periods. "Long-term" aquifer yields during normal

Specific Yield-- Compilation of Specific Yields for Various Materials

GEOLOGICAL SURVEY WATER SUPPLY PAPER 1662-D

Prepared in cooperation with the California Department of Water Resources

HYDROLOGIC PROPERTIES OF EARTH MATERIALS

SPECIFIC YIELD—COMPILATION OF SPECIFIC YIELDS FOR VARIOUS MATERIALS

By A. I. Johnson

ABSTRACT

Specific yield is defined as the ratio of (1) the volume of water that a saturated rock or soil will yield by gravity to (2) the total volume of the rock or soil. Specific yield is usually expressed as a percentage. The value is not definitive, because the quantity of water that will drain by gravity depends on variables such as duration of drainage, temperature, mineral composition of the water, and various physical characteristics of the rock or soil under consideration. Values of specific yield, nevertheless, offer a convenient means by which hydrologists can estimate the water-yielding capacities of earth materials and, as such, are very useful in hydrologic studies.

The present report consists mostly of direct or modified quotations from many selected reports that present and evaluate methods for determining specific yield, limitations of those methods, and results of the determinations made on a wide variety of rock and soil materials. Although no particular values are recommended in this report, a table summarizes values of specific yield, and their averages, determined for 10 rock textures. The following is an abstract of the table:

Specific yields, in percent, of various materials

[Rounded to nearest whole percent]

Material	*Number of determinations*	*Specific yield*		
		Maximum	*Minimum*	*Average*
Clay	15	5	0	2
Silt	16	19	3	8
Sandy clay	12	12	3	7
Fine sand	17	28	10	21
Medium sand	17	32	15	26
Coarse sand	17	35	20	27
Gravelly sand	15	35	20	25
Fine gravel	17	35	21	25
Medium gravel	14	26	13	23
Coarse gravel	14	26	12	22

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this report is to assist hydrologists in estimating the quantity of water in storage in ground-water reservoirs by providing

Attachment 6
Site Owner's Manual

Site Owner’s Manual

COAL MINE BROOK

616 Plantation Street
Worcester, Massachusetts

Prepared for:
City of Worcester
Mr. Robert Antonelli, Assistant Commissioner
c/o Cesar Valiente, Project Manager
Department of Public Works and Parks
50 Skyline Drive
Worcester, MA 01605

Prepared by:

BEALS + THOMAS

January 5, 2022

TABLE OF CONTENTS

FIGURES

APPENDICES

1.0 INTRODUCTION

The Site Owner's Manual complies with the Long-Term Pollution Prevention Plan (Standard 4) and the Long-Term Operation and Maintenance Plan (Standard 9) requirements of the 2008 Massachusetts Department of Environmental Protection (DEP) Stormwater Handbook. The Manual outlines source control and pollution prevention measures and maintenance requirements of stormwater best management practices (BMPs) associated with the proposed development.

2.0 SITE OWNER'S AGREEMENT

2.1 Operation and Maintenance Compliance Statement

Site Owner: City of Worcester
50 Skyline Drive
Worcester, MA 01605

Responsible Party: City of Worcester

The City of Worcester or their successors shall maintain ownership of the on-site stormwater management system as well as the responsibility for operation and maintenance during the post-development stages of the project. The site has been inspected for erosion and appropriate measures have been taken to permanently stabilize any eroded areas. All aspects of stormwater best management practices (BMPs) have been inspected for damage, wear and malfunction, and appropriate steps have been taken to repair or replace the system or portions of the system so that the stormwater at the site may be managed in accordance with the Stormwater Management Standards. Future responsible parties shall be notified of their continuing legal responsibility to operate and maintain the BMPs. The operation and maintenance plan for the stormwater BMPs is being implemented.

01/04/2022

Responsible Party Signature　　　　Date

2.2 Stormwater Maintenance Easements

There are no off-site areas utilized for stormwater control, therefore no stormwater management easements are required. The Site Owner will have access to all stormwater practices for inspection and maintenance, including direct maintenance access by heavy equipment to structures requiring regular maintenance.

2.3 Record Keeping

The Site Owner shall maintain a rolling log in which all inspections and maintenance activities for the past three years shall be recorded. The Operation and Maintenance Log includes information pertaining to inspections, repairs, and disposal relevant to the project's stormwater management system. The Log is located in Appendix A.

The Operation and Maintenance Log shall be made available to the Conservation Commission and the DEP upon request. The Conservation Commission and the DEP shall be allowed to enter and inspect the premises to evaluate and ensure that the responsible party complies with the maintenance requirements for each BMP.

2.4 Training

Employees involved in grounds maintenance and emergency response will be educated on the general concepts of stormwater management and groundwater protection. The Site Owner's Manual will be reviewed with the maintenance staff. The staff will be trained on the proper course of action for specific events expected to be incurred during routine maintenance or emergency situations.

3.0 LONG-TERM POLLUTION PREVENTION PLAN

In compliance with Standard 4 of the 2008 DEP Stormwater Management Handbook, this section outlines source control and pollution prevention measures to be employed on-site after construction.

3.1 Storage of Materials and Waste

The site shall be kept clear of trash and debris at all times. Certain materials and waste products shall be stored inside or outside upon an impervious surface and covered, as required by local and state regulations.

3.2 Vehicle Washing

No commercial vehicle washing shall take place on site.

3.3 Routine Inspections and Maintenance of Stormwater BMPs

See Section 4.0 Long-Term Operation and Maintenance Plan, for routine inspection and maintenance requirements for all proposed stormwater BMPs.

3.4 Spill Prevention and Response

A contingency plan shall be implemented to address the spill or release of petroleum products and hazardous materials and will include the following measures:

1. Equipment necessary to quickly attend to inadvertent spills or leaks shall be stored on-site in a secure but accessible location. Such equipment shall include but not be limited to the following: safety goggles, chemically resistant gloves and overshoe boots, water and chemical fire extinguishers, sand and shovels, suitable absorbent materials, storage containers and first aid equipment (i.e. Indian Valley Industries, Inc. 55-gallon Spill Containment kit or approved equivalent).

2. Spills or leaks shall be treated properly according to material type, volume of spillage and location of spill. Mitigation shall include preventing further spillage, containing the spilled material in the smallest practical area, removing spilled material in a safe and environmentally-friendly manner, and remediation of any damage to the environment.

3. For large spills, Massachusetts DEP Hazardous Waste Incident Response Group shall be notified immediately at 888-304-1133 and an emergency response contractor shall be consulted.

3.5 Maintenance of Lawns, Gardens, and other Landscaped Areas

Lawns, gardens, and other landscaped areas shall be maintained regularly by the site owner. Vegetated and landscaped BMPs will be maintained as outlined in Section 4.0.

3.6 Storage and Use of Fertilizers, Herbicides, and Pesticides

All fertilizers, herbicides, and pesticides shall be stored in accordance with local, state, and federal regulations. The application rate and use of fertilizers, herbicides, and pesticides on the site shall at no time exceed local, state, or federal specifications.

3.7 Pet Waste Management

Pet owners shall be required to pick up after their animals and dispose of waste in the trash.

3.8 Snow and Deicing Chemical Management

Snow removal and use of deicing chemicals at the proposed development shall comply with the following requirements:

- Plowed snow shall be placed in the areas designated on the site plans and/or outside of wetland boundaries and stormwater best management practices. The following maintenance measures shall be undertaken at all snow disposal sites:
  - Debris shall be cleared from an area prior to using it for snow disposal.
  - Debris and accumulated sediments shall be cleared from the site and properly disposed of at the end of the snow season and no later than May 15.
- In accordance with the Massachusetts General Laws, Chapter 85, Section 7A, salt and other de-icing chemicals will be stored at an indoor location. Salt and other deicing chemicals shall be stored in accordance with Massachusetts General Law.
- Sand piles shall be contained and stabilized to prevent the discharge of sand to wetlands or water bodies, and, where feasible, covered.
- Salt storage piles shall be located outside of the 100-year floodplain.
- The application of salt on the proposed parking areas and driveway shall at no time exceed state or local requirements.

4.0 LONG-TERM OPERATION AND MAINTENANCE PLAN

This section outlines the stormwater best management practices (BMPs) associated with the proposed stormwater management system and identifies the long-term inspection and maintenance requirements for each BMP.

4.1 Stormwater Management System Components

The following table outlines the type and quantity of the BMPs and their general location. Please reference the site plan(s) provided in the Figures section for exact location.

BMP Type	Quantity	Location
Catch Basins	2	Throughout paved parking area.
Area Drain	2	Eastern portion of lawn area.
Water Quality Unit	2	Throughout paved parking area
Subsurface Infiltration Structures	2	Throughout paved parking area and eastern portion of lawn area.

4.2 Inspection and Maintenance Schedules

4.2.1 Deep Sump and Hooded Catch Basins

Catch basins shall be inspected four times per year, including after the foliage season. Other inspection and maintenance requirements include:

- Units shall be cleaned (organic material, sediment and hydrocarbons removed) four times per year or whenever the depth of deposits is greater than or equal to one half the depth from the bottom of the invert of the lowest pipe in the basin.
  - Cleanout shall always occur after street sweeping.
- If any evidence of hydrocarbons is found during inspection, the material shall be immediately removed using absorbent pads or other suitable measures and disposed of legally.
- Remove other accumulated debris as necessary.
- Transport and disposal of accumulated sediment off-site shall be in accordance with applicable local, state and federal guidelines and regulations.

4.2.2 Area Drains and Drop Inlets

Area drains and drop inlets shall be inspected and/or cleaned at least once per year.

4.2.3 Proprietary Separators

Maintenance of proprietary separators shall be performed according the recommendations set forth by the manufacturer (see Appendix C. Proprietary Separator Technical Manual for complete installation, operation and maintenance procedures). Inspection and maintenance procedures for proprietary devices are provided below:

- Units shall be inspected post-construction, prior to being put into service.
- Units shall be inspected not less than twice per year following installation and no less than once per year thereafter.
- Units shall be inspected immediately after any oil, fuel or chemical spill.
- All inspections shall include checking the oil level and sediment depth in the unit.
- Removal of sediments/oils shall occur per manufacturer recommendations.
- A licensed waste management company shall remove captured petroleum waste products from any oil, chemical or fuel spills and dispose.
- OSHA confined space entry protocols shall be followed if entry into the unit is required.

4.2.4 Subsurface Infiltration Structures

Subsurface infiltration structures shall be inspected twice per year. The inlets shall be inspected, and all debris that may clog the system shall be removed.

4.3 Estimated Operation and Maintenance Budget

An operations and maintenance budget was prepared to approximate the annual cost of the inspections required in compliance with the DEP Stormwater Management Policy. The table below estimates the annual cost to inspect and maintain each proposed BMP, based on the requirements in Section 4.2.

BMP Type	# of BMPS	Annual O&M Cost (per BMP)[1]	Total Cost
Catch Basin	2	$200-$400	$400-$800
Area Drain/Drop Inlet	2	$50-$100	$100-$200
Water Quality Unit	2	$100-$300	$200-$600
Subsurface Infiltration Structures	2	$200-$400	$400-$800
		Total	$1100-$2400

4.4 Public Safety Features

Multiple safety measures are proposed to protect the public and prevent pollutant contamination of the stormwater management system and other water resources. Guardrails and proposed curbing along the access driveway and parking areas will prevent cars from inadvertently detouring down steep side slopes. It was designed to ensure protection to the public and prevent pollutant contamination of the stormwater management system and the municipal drainage system.

[1] Annual maintenance cost is based on estimate of the cost to complete all inspection and maintenance measures outlined in Section 4.2. For BMPs that require sediment removal at regular intervals (i.e. every 5 or 10 years), the annual cost includes the annual percentage of that cost.

Figures

Figure 1: Site Plan

FOR NOTES, REFERENCES AND LEGEND SEE SHEET C1.1.

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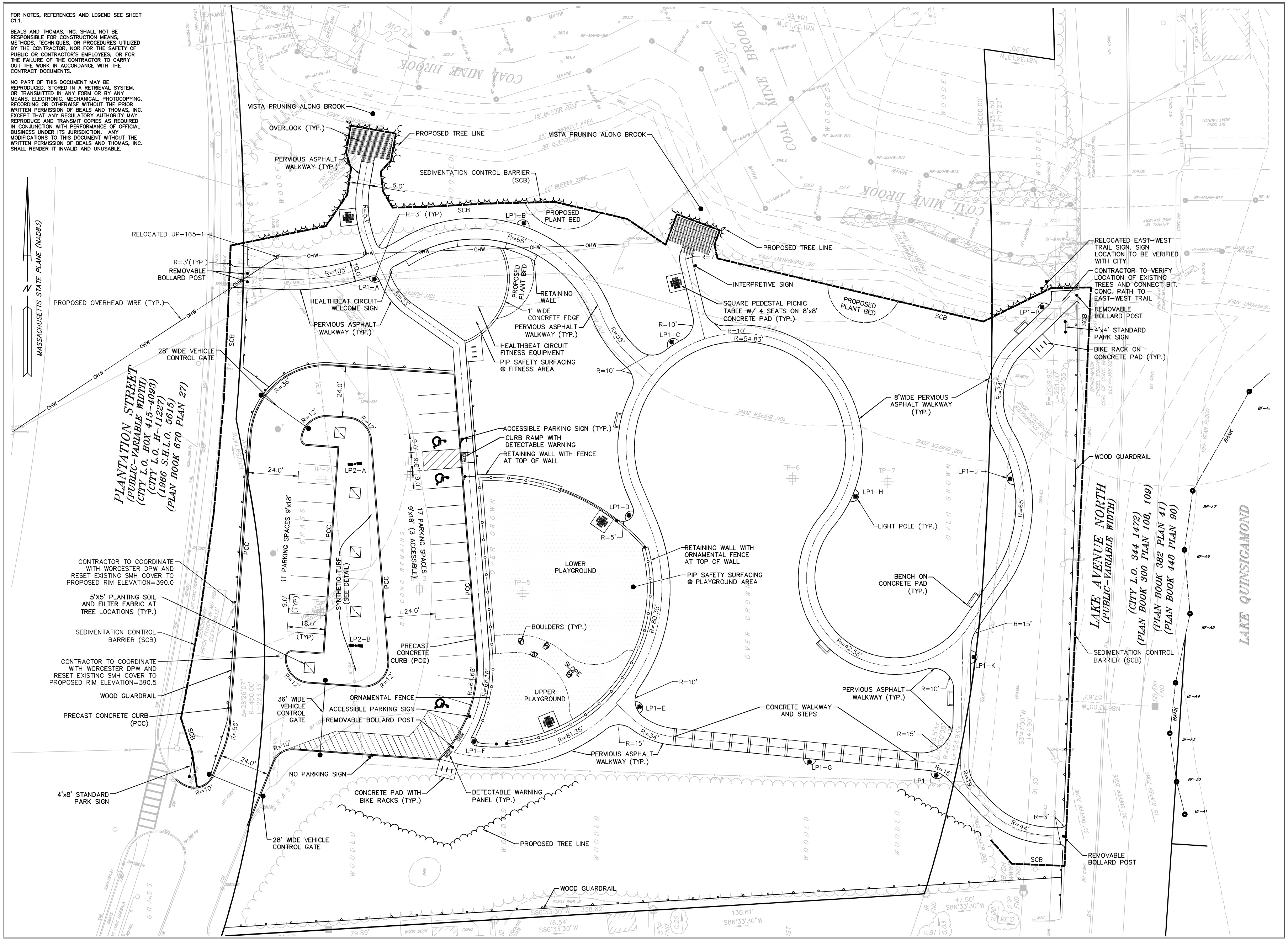

PREPARED FOR:

CITY OF WORCESTER
50 SKYLINE DRIVE
WORCESTER, MASSACHUSETTS

01/05/2022

FOR PERMITTING ONLY

PREPARED BY:

BEALS + THOMAS

BEALS AND THOMAS, INC.
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	ISSUE DATE	DESCRIPTION
5		
4		
3		
2		
1		
0	01/05/2022	PERMIT PLAN SET

NBB	NBB	DMG	DMG/DJL
DES	DWN	CHK'D	APP'D

PROJECT:

COAL MINE BROOK
616 PLANTATION STREET
WORCESTER, MASSACHUSETTS

SCALE: 1" = 20' DATE: JANUARY 5, 2022

LAYOUT AND MATERIALS PLAN

B+T JOB NO.3228.01
B+T PLAN NO. 322800P003A-002

C3.1

FOR NOTES, REFERENCES AND LEGEND SEE SHEET C1.1.

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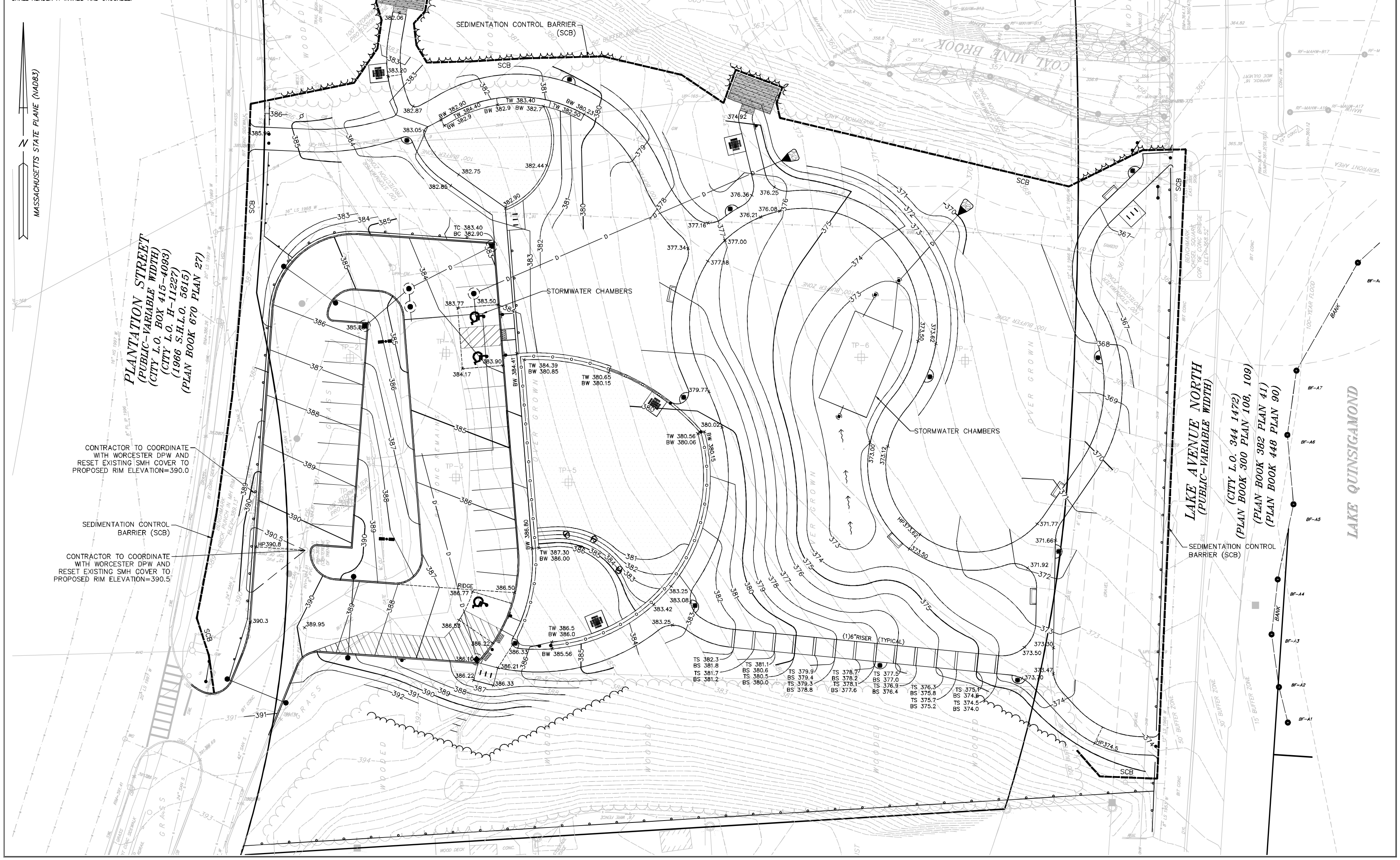

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5			
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	ISSUE DATE	DESCRIPTION	
NBB	NBB	DMG	DMG/DJL
DES	DWN	CHK'D	APP'D

PROJECT:

COAL MINE BROOK

616 PLANTATION STREET
WORCESTER, MASSACHUSETTS

SCALE: 1" = 20' DATE: JANUARY 5, 2022

METERS 0 5 10 15
FEET 0 10 20 40 60

GRADING PLAN

B+T JOB NO.3228.01

B+T PLAN NO. 322800P003A-003

C4.1

FOR NOTES, REFERENCES AND LEGEND SEE SHEET C1.1.

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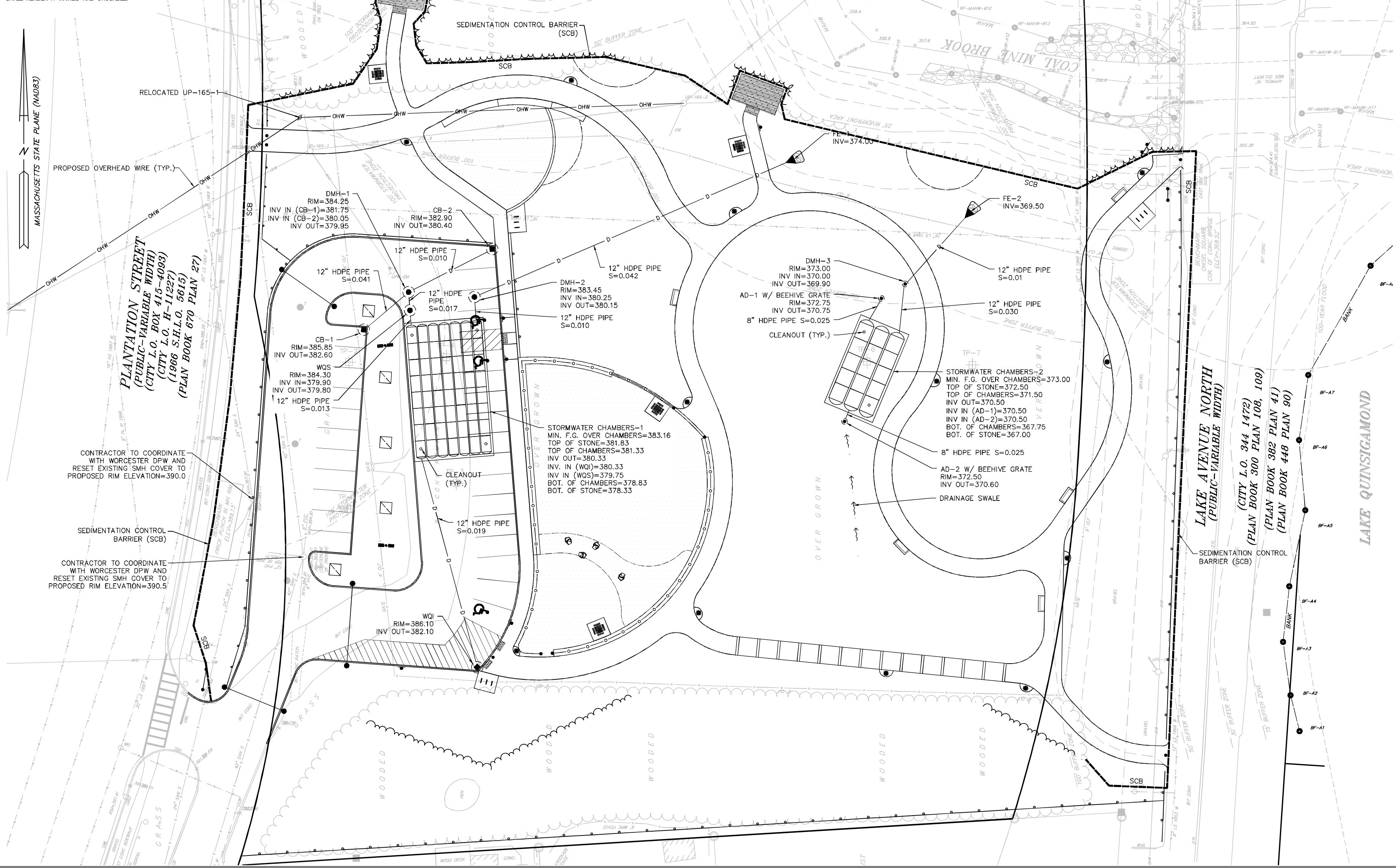

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	ISSUE DATE	DESCRIPTION
5		
4		
3		
2		
1		
0	01/05/2022	PERMIT PLAN SET

NBB	NBB	DMG	DMG
DES	DWN	CHK'D	APP'D

PROJECT:

COAL MINE BROOK
616 PLANTATION STREET
WORCESTER, MASSACHUSETTS

SCALE: 1" = 20' DATE: JANUARY 5, 2022

METERS 0 5 10 15
FEET 0 10 20 40 60

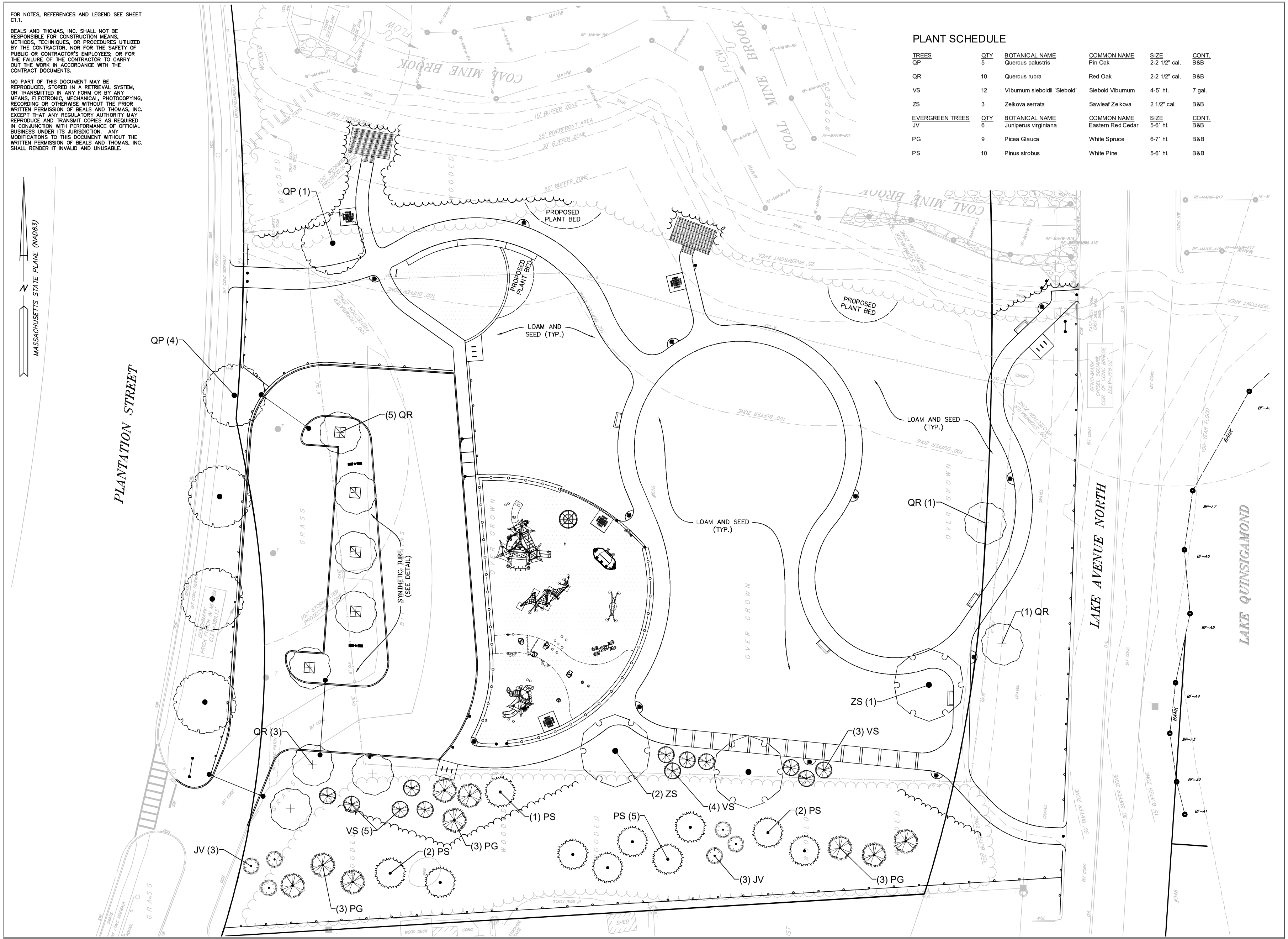
UTILITY PLAN

B+T JOB NO.3228.01
B+T PLAN NO. 322800P003A-004

C5.1

FOR NOTES, REFERENCES AND LEGEND SEE SHEET C1.1.

BEALS AND THOMAS, INC. SHALL NOT BE RESPONSIBLE FOR CONSTRUCTION MEANS, METHODS, TECHNIQUES, OR PROCEDURES UTILIZED BY THE CONTRACTOR, NOR FOR THE SAFETY OF PUBLIC OR CONTRACTOR'S EMPLOYEES; OR FOR THE FAILURE OF THE CONTRACTOR TO CARRY OUT THE WORK IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.



PLANT SCHEDULE

TREES	QTY	BOTANICAL NAME	COMMON NAME	SIZE	CONT.
QP	5	Quercus palustris	Pin Oak	2-2 1/2" cal.	B&B
QR	10	Quercus rubra	Red Oak	2-2 1/2" cal.	B&B
VS	12	Viburnum sieboldii 'Siebold'	Siebold Viburnum	4-5' ht.	7 gal.
ZS	3	Zelkova serrata	Sawleaf Zelkova	2 1/2" cal.	B&B
EVERGREEN TREES	**QTY**	**BOTANICAL NAME**	**COMMON NAME**	**SIZE**	**CONT.**
JV	6	Juniperus virginiana	Eastern Red Cedar	5-6' ht.	B&B
PG	9	Picea Glauca	White Spruce	6-7' ht.	B&B
PS	10	Pinus strobus	White Pine	5-6' ht.	B&B

PREPARED FOR:

CITY OF WORCESTER
50 SKYLINE DRIVE
WORCESTER, MASSACHUSETTS

01/05/2022

FOR PERMITTING ONLY

PREPARED BY:

BEALS+THOMAS
BEALS AND THOMAS, INC.
144 Turnpike Road
Southborough, Massachusetts 01772-2104
T 508.366.0560 | www.bealsandthomas.com

	ISSUE DATE	DESCRIPTION
5		
4		
3		
2		
1		
0	01/05/2022	PERMIT PLAN SET

LAC	LAC	DJL	DJL
DES	DWN	CHK'D	APP'D

PROJECT:

COAL MINE BROOK
616 PLANTATION STREET
WORCESTER, MASSACHUSETTS

SCALE: 1" = 20' DATE: JANUARY 5, 2022

METERS 0 5 10 15
FEET 0 10 20 40 60

LANDSCAPE AND LIGHTING PLAN

B+T JOB NO.3228.01
B+T PLAN NO. 322800P003A-005

C6.1

Appendices

Appendix A

Operation and Maintenance Log

OPERATION AND MAINTENANCE LOG

This template is intended to comply with the operation and maintenance log requirements of the 2008 DEP Stormwater Management Handbook. Copies of this log should be made for all inspections and kept on file for three years from the inspection date.

Name/Company of Inspector:	
Date/Time of Inspection:	
Weather Conditions: (Note current weather and any recent precipitation events)	

Stormwater BMP	Inspection Observations	Actions Required

Appendix B

List of Emergency Contacts

List of Emergency Contacts

Massachusetts DEP Hazardous Waste Incident Response Group
(617) 792-7653

City of Worcester Fire Department
Emergencies: Dial 911
141 Grove Street
Worcester, MA 01605
Tel: (508) 799-1821
Fire Chief: Michael J. Lavoie

City of Worcester Police Department
Emergencies: Dial 911
9-11 Lincoln Square
Worcester, MA 01608
Tel: (508) 799-8600
Police Chief: Steven M. Sargent

Appendix C

Proprietary Separator Technical Manual

CDS Guide
Operation, Design, Performance and Maintenance

CDS®

Using patented continuous deflective separation technology, the CDS system screens, separates and traps debris, sediment, and oil and grease from stormwater runoff. The indirect screening capability of the system allows for 100% removal of floatables and neutrally buoyant material without blinding. Flow and screening controls physically separate captured solids, and minimize the re-suspension and release of previously trapped pollutants. Inline units can treat up to 6 cfs, and internally bypass flows in excess of 50 cfs (1416 L/s). Available precast or cast-in-place, offline units can treat flows from 1 to 300 cfs (28.3 to 8495 L/s). The pollutant removal capacity of the CDS system has been proven in lab and field testing.

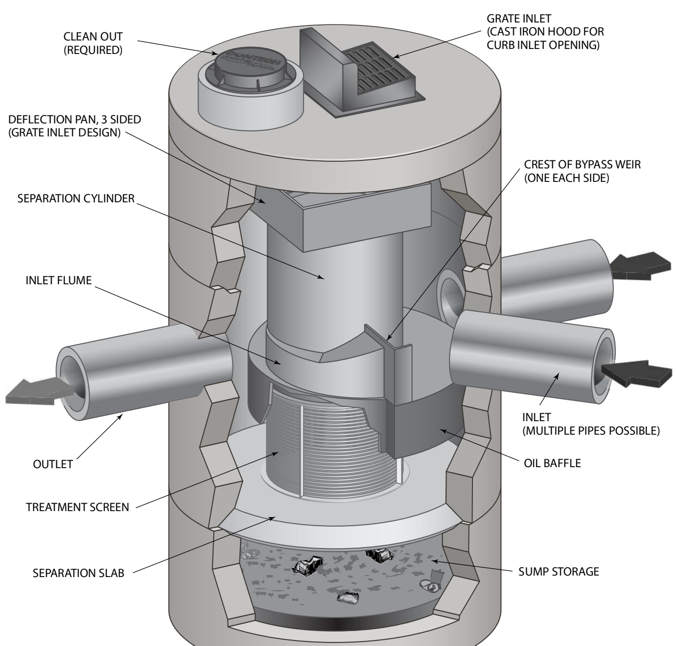
Operation Overview

Stormwater enters the diversion chamber where the diversion weir guides the flow into the unit's separation chamber and pollutants are removed from the flow. All flows up to the system's treatment design capacity enter the separation chamber and are treated.

Swirl concentration and screen deflection force floatables and solids to the center of the separation chamber where 100% of floatables and neutrally buoyant debris larger than the screen apertures are trapped.

Stormwater then moves through the separation screen, under the oil baffle and exits the system. The separation screen remains clog free due to continuous deflection.

During the flow events exceeding the treatment design capacity, the diversion weir bypasses excessive flows around the separation chamber, so captured pollutants are retained in the separation cylinder.



Design Basics

There are three primary methods of sizing a CDS system. The Water Quality Flow Rate Method determines which model size provides the desired removal efficiency at a given flow rate for a defined particle size. The Rational Rainfall Method™ or the and Probabilistic Method is used when a specific removal efficiency of the net annual sediment load is required.

Typically in the Unites States, CDS systems are designed to achieve an 80% annual solids load reduction based on lab generated performance curves for a gradation with an average particle size (d50) of 125 microns (μm). For some regulatory environments, CDS systems can also be designed to achieve an 80% annual solids load reduction based on an average particle size (d50) of 75 microns (μm) or 50 microns (μm).

Water Quality Flow Rate Method

In some cases, regulations require that a specific treatment rate, often referred to as the water quality design flow (WQQ), be treated. This WQQ represents the peak flow rate from either an event with a specific recurrence interval, e.g. the six-month storm, or a water quality depth, e.g. 1/2-inch (13 mm) of rainfall.

The CDS is designed to treat all flows up to the WQQ. At influent rates higher than the WQQ, the diversion weir will direct most flow exceeding the WQQ around the separation chamber. This allows removal efficiency to remain relatively constant in the separation chamber and eliminates the risk of washout during bypass flows regardless of influent flow rates.

Treatment flow rates are defined as the rate at which the CDS will remove a specific gradation of sediment at a specific removal efficiency. Therefore the treatment flow rate is variable, based on the gradation and removal efficiency specified by the design engineer.

Rational Rainfall Method™

Differences in local climate, topography and scale make every site hydraulically unique. It is important to take these factors into consideration when estimating the long-term performance of any stormwater treatment system. The Rational Rainfall Method combines site-specific information with laboratory generated performance data, and local historical precipitation records to estimate removal efficiencies as accurately as possible.

Short duration rain gauge records from across the United States and Canada were analyzed to determine the percent of the total annual rainfall that fell at a range of intensities. US stations' depths were totaled every 15 minutes, or hourly, and recorded in 0.01-inch increments. Depths were recorded hourly with 1-mm resolution at Canadian stations. One trend was consistent at all sites; the vast majority of precipitation fell at low intensities and high intensity storms contributed relatively little to the total annual depth.

These intensities, along with the total drainage area and runoff coefficient for each specific site, are translated into flow rates using the Rational Rainfall Method. Since most sites are relatively small and highly impervious, the Rational Rainfall Method is appropriate. Based on the runoff flow rates calculated for each intensity, operating rates within a proposed CDS system are determined. Performance efficiency curve determined from full scale laboratory tests on defined sediment PSDs is applied to calculate solids removal efficiency. The relative removal efficiency at each operating rate is added to produce a net annual pollutant removal efficiency estimate.

Probabilistic Rational Method

The Probabilistic Rational Method is a sizing program Contech developed to estimate a net annual sediment load reduction for a particular CDS model based on site size, site runoff coefficient, regional rainfall intensity distribution, and anticipated pollutant characteristics.

The Probabilistic Method is an extension of the Rational Method used to estimate peak discharge rates generated by storm events of varying statistical return frequencies (e.g. 2-year storm event). Under the Rational Method, an adjustment factor is used to adjust the runoff coefficient estimated for the 10-year event, correlating a known hydrologic parameter with the target storm event. The rainfall intensities vary depending on the return frequency of the storm event under consideration. In general, these two frequency dependent parameters (rainfall intensity and runoff coefficient) increase as the return frequency increases while the drainage area remains constant.

These intensities, along with the total drainage area and runoff coefficient for each specific site, are translated into flow rates using the Rational Method. Since most sites are relatively small and highly impervious, the Rational Method is appropriate. Based on the runoff flow rates calculated for each intensity, operating rates within a proposed CDS are determined. Performance efficiency curve on defined sediment PSDs is applied to calculate solids removal efficiency. The relative removal efficiency at each operating rate is added to produce a net annual pollutant removal efficiency estimate.

Treatment Flow Rate

The inlet throat area is sized to ensure that the WQQ passes through the separation chamber at a water surface elevation equal to the crest of the diversion weir. The diversion weir bypasses excessive flows around the separation chamber, thus preventing re-suspension or re-entrainment of previously captured particles.

Hydraulic Capacity

The hydraulic capacity of a CDS system is determined by the length and height of the diversion weir and by the maximum allowable head in the system. Typical configurations allow hydraulic capacities of up to ten times the treatment flow rate. The crest of the diversion weir may be lowered and the inlet throat may be widened to increase the capacity of the system at a given water surface elevation. The unit is designed to meet project specific hydraulic requirements.

Performance

Full-Scale Laboratory Test Results

A full-scale CDS system (Model CDS2020-5B) was tested at the facility of University of Florida, Gainesville, FL. This CDS unit was evaluated under controlled laboratory conditions of influent flow rate and addition of sediment.

Two different gradations of silica sand material (UF Sediment & OK-110) were used in the CDS performance evaluation. The particle size distributions (PSDs) of the test materials were analyzed using standard method "Gradation ASTM D-422 "Standard Test Method for Particle-Size Analysis of Soils" by a certified laboratory.

UF Sediment is a mixture of three different products produced by the U.S. Silica Company: "Sil-Co-Sil 106", "#1 DRY" and "20/40 Oil Frac". Particle size distribution analysis shows that the UF Sediment has a very fine gradation (d50 = 20 to 30 μm) covering a wide size range (Coefficient of Uniformity, C averaged at 10.6). In comparison with the hypothetical TSS gradation specified in the NJDEP (New Jersey Department of Environmental Protection) and NJCAT (New Jersey Corporation for Advanced Technology) protocol for lab testing, the UF Sediment covers a similar range of particle size but with a finer d50 (d50 for NJDEP is approximately 50 μm) (NJDEP, 2003).

The OK-110 silica sand is a commercial product of U.S. Silica Sand. The particle size distribution analysis of this material, also included in Figure 1, shows that 99.9% of the OK-110 sand is finer than 250 microns, with a mean particle size (d50) of 106 microns. The PSDs for the test material are shown in Figure 1.

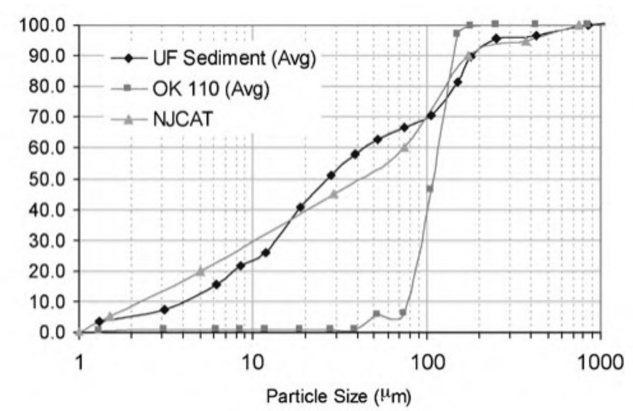


Figure 1. Particle size distributions

Tests were conducted to quantify the performance of a specific CDS unit (1.1 cfs (31.3-L/s) design capacity) at various flow rates, ranging from 1% up to 125% of the treatment design capacity of the unit, using the 2400 micron screen. All tests were conducted with controlled influent concentrations of approximately 200 mg/L. Effluent samples were taken at equal time intervals across the entire duration of each test run. These samples were then processed with a Dekaport Cone sample splitter to obtain representative sub-samples for Suspended Sediment Concentration (SSC) testing using ASTM D3977-97 "Standard Test Methods for Determining Sediment Concentration in Water Samples", and particle size distribution analysis.

Results and Modeling

Based on the data from the University of Florida, a performance model was developed for the CDS system. A regression analysis was used to develop a fitting curve representative of the scattered data points at various design flow rates. This model, which demonstrated good agreement with the laboratory data, can then be used to predict CDS system performance with respect to SSC removal for any particle size gradation, assuming the particles are inorganic sandy-silt. Figure 2 shows CDS predictive performance for two typical particle size gradations (NJCAT gradation and OK-110 sand) as a function of operating rate.

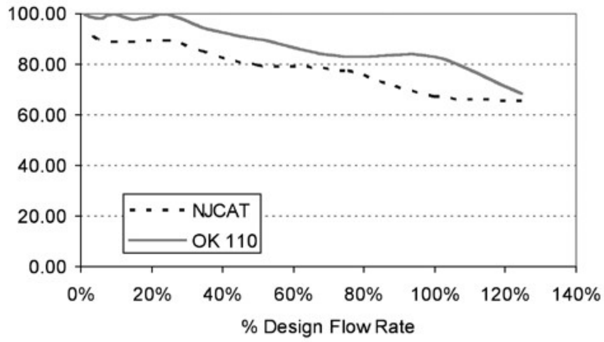


Figure 2. CDS stormwater treatment predictive performance for various particle gradations as a function of operating rate.

Many regulatory jurisdictions set a performance standard for hydrodynamic devices by stating that the devices shall be capable of achieving an 80% removal efficiency for particles having a mean particle size (d50) of 125 microns (e.g. Washington State Department of Ecology — WASDOE - 2008). The model can be used to calculate the expected performance of such a PSD (shown in Figure 3). The model indicates (Figure 4) that the CDS system with 2400 micron screen achieves approximately 80% removal at the design (100%) flow rate, for this particle size distribution (d50 = 125 μm).

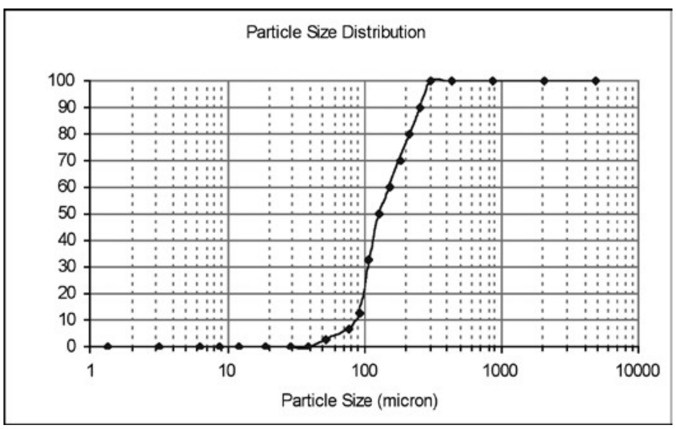


Figure 3. WASDOE PSD

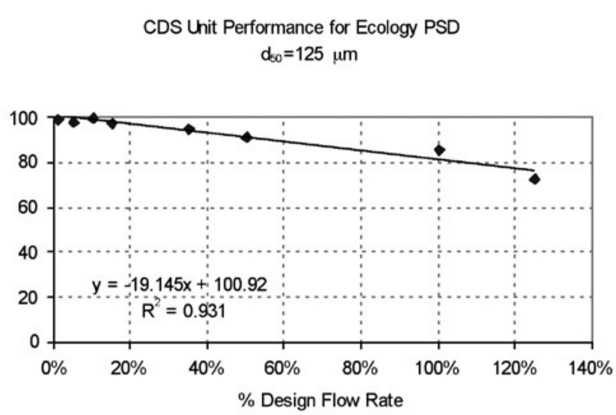


Figure 4. Modeled performance for WASDOE PSD.

Maintenance

The CDS system should be inspected at regular intervals and maintained when necessary to ensure optimum performance. The rate at which the system collects pollutants will depend more heavily on site activities than the size of the unit. For example, unstable soils or heavy winter sanding will cause the grit chamber to fill more quickly but regular sweeping of paved surfaces will slow accumulation.

Inspection

Inspection is the key to effective maintenance and is easily performed. Pollutant transport and deposition may vary from year to year and regular inspections will help ensure that the system is cleaned out at the appropriate time. At a minimum, inspections should be performed twice per year (e.g. spring and fall) however more frequent inspections may be necessary in climates where winter sanding operations may lead to rapid accumulations, or in equipment washdown areas. Installations should also be inspected more frequently where excessive amounts of trash are expected.

The visual inspection should ascertain that the system components are in working order and that there are no blockages or obstructions in the inlet and separation screen. The inspection should also quantify the accumulation of hydrocarbons, trash, and sediment in the system. Measuring pollutant accumulation can be done with a calibrated dipstick, tape measure or other measuring instrument. If absorbent material is used for enhanced removal of hydrocarbons, the level of discoloration of the sorbent material should also be identified

during inspection. It is useful and often required as part of an operating permit to keep a record of each inspection. A simple form for doing so is provided.

Access to the CDS unit is typically achieved through two manhole access covers. One opening allows for inspection and cleanout of the separation chamber (cylinder and screen) and isolated sump. The other allows for inspection and cleanout of sediment captured and retained outside the screen. For deep units, a single manhole access point would allows both sump cleanout and access outside the screen.

The CDS system should be cleaned when the level of sediment has reached 75% of capacity in the isolated sump or when an appreciable level of hydrocarbons and trash has accumulated. If absorbent material is used, it should be replaced when significant discoloration has occurred. Performance will not be impacted until 100% of the sump capacity is exceeded however it is recommended that the system be cleaned prior to that for easier removal of sediment. The level of sediment is easily determined by measuring from finished grade down to the top of the sediment pile. To avoid underestimating the level of sediment in the chamber, the measuring device must be lowered to the top of the sediment pile carefully. Particles at the top of the pile typically offer less resistance to the end of the rod than consolidated particles toward the bottom of the pile. Once this measurement is recorded, it should be compared to the as-built drawing for the unit to determine weather the height of the sediment pile off the bottom of the sump floor exceeds 75% of the total height of isolated sump.

Cleaning

Cleaning of a CDS systems should be done during dry weather conditions when no flow is entering the system. The use of a vacuum truck is generally the most effective and convenient method of removing pollutants from the system. Simply remove the manhole covers and insert the vacuum hose into the sump. The system should be completely drained down and the sump fully evacuated of sediment. The area outside the screen should also be cleaned out if pollutant build-up exists in this area.

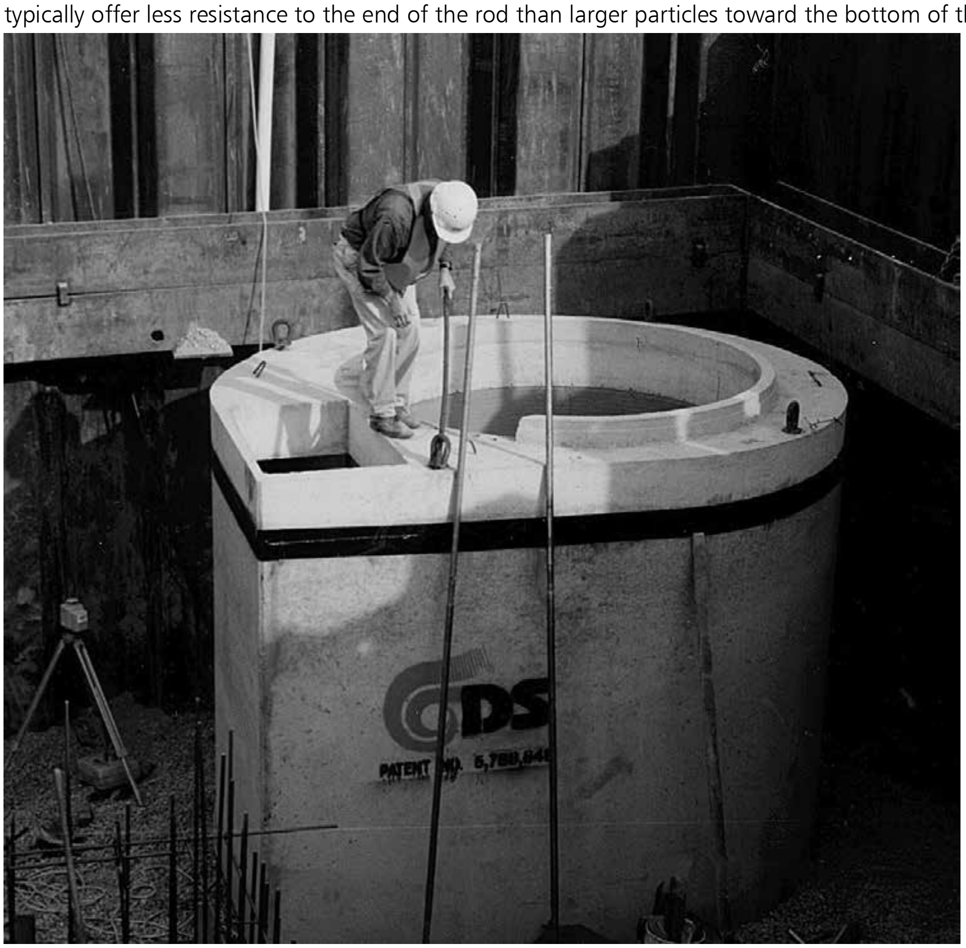
In installations where the risk of petroleum spills is small, liquid contaminants may not accumulate as quickly as sediment. However, the system should be cleaned out immediately in the event of an oil or gasoline spill. Motor oil and other hydrocarbons that accumulate on a more routine basis should be removed when an appreciable layer has been captured. To remove these pollutants, it may be preferable to use absorbent pads since they are usually less expensive to dispose than the oil/water emulsion that may be created by vacuuming the oily layer. Trash and debris can be netted out to separate it from the other pollutants. The screen should be cleaned to ensure it is free of trash and debris.

Manhole covers should be securely seated following cleaning activities to prevent leakage of runoff into the system from above and also to ensure that proper safety precautions have been followed. Confined space entry procedures need to be followed if physical access is required. Disposal of all material removed from the CDS system should be done in accordance with local regulations. In many jurisdictions, disposal of the sediments may be handled in the same manner as the disposal of sediments removed from catch basins or deep sump manholes. Check your local regulations for specific requirements on disposal.

CDS Model	Diameter		Distance from Water Surface to Top of Sediment Pile		Sediment Storage Capacity	
	ft	m	ft	m	y³	m³
CDS1515	3	0.9	3.0	0.9	0.5	0.4
CDS2015	4	1.2	3.0	0.9	0.9	0.7
CDS2015	5	1.5	3.0	0.9	1.3	1.0
CDS2020	5	1.5	3.5	1.1	1.3	1.0
CDS2025	5	1.5	4.0	1.2	1.3	1.0
CDS3020	6	1.8	4.0	1.2	2.1	1.6
CDS3025	6	1.8	4.0	1.2	2.1	1.6
CDS3030	6	1.8	4.6	1.4	2.1	1.6
CDS3035	6	1.8	5.0	1.5	2.1	1.6
CDS4030	8	2.4	4.6	1.4	5.6	4.3
CDS4040	8	2.4	5.7	1.7	5.6	4.3
CDS4045	8	2.4	6.2	1.9	5.6	4.3
CDS5640	10	3.0	6.3	1.9	8.7	6.7
CDS5653	10	3.0	7.7	2.3	8.7	6.7
CDS5668	10	3.0	9.3	2.8	8.7	6.7
CDS5678	10	3.0	10.3	3.1	8.7	6.7

Table 1: CDS Maintenance Indicators and Sediment Storage Capacities

Note: To avoid underestimating the volume of sediment in the chamber, carefully lower the measuring device to the top of the sediment pile. Finer silty particles at the top of the pile may be more difficult to feel with a measuring stick. These finer particles typically offer less resistance to the end of the rod than larger particles toward the bottom of the pile.



CDS Inspection & Maintenance Log

CDS Model: ______________________ Location: ______________________

Date	Water depth to sediment[1]	Floatable Layer Thickness[2]	Describe Maintenance Performed	Maintenance Personnel	Comments

1. The water depth to sediment is determined by taking two measurements with a stadia rod: one measurement from the manhole opening to the top of the sediment pile and the other from the manhole opening to the water surface. If the difference between these measurements is less than the values listed in table 1 the system should be cleaned out. **Note: to avoid underestimating the volume of sediment in the chamber, the measuring device must be carefully lowered to the top of the sediment pile**.

2. For optimum performance, the system should be cleaned out when the floating hydrocarbon layer accumulates to an appreciable thickness. In the event of an oil spill, the system should be cleaned immediately.

SUPPORT

- Drawings and specifications are available at www.ContechES.com.
- Site-specific design support is available from our engineers.

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